W. B. No. 699.

U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

CHARLES F. MARVIN, Chief

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions and bibliography including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological table dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (a) Results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; and (b) abstracts or reviews of important meteorological papers and books, and (c) notes. In each issue of the REVIEW reviews, abstracts, and notes are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather; applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of such contributions is not to be construed as official approval of the views expressed.

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW.

The section on the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

SUPPLEMENTS containing kite observations and others containing monographs or specialized groups of papers are published from time to time.

NOTES TO CONTRIBUTORS.

Authors are requested to accompany their papers submitted for publication with a brief opening synopsis. When an article deals with more than one subject—as, for example, a method of measurement—some experimental results and a theory, each subject should be summarized in a *separate paragraph*, with a title which clearly describes it.

When illustrations accompany an article submitted for publication in the MONTHLY WEATHER REVIEW, the places where they should appear in the text should be indicated, and legends or titles for them should be inserted just after the end of the article. As far as practicable the illustrations when accompanied by their legends should be self-explanatory—i. e., the data on them should leave no doubt of what they are intended to convey.

SOME WEATHER BUREAU PUBLICATIONS.

Serial numbers of Weather Bureau publications	Free.
The Weather Bureau. (Descriptive pamphlet)	Free.
Report of the Chief of the Weather Bureau, 1917–18 (4° edition)	Free.
National Weather and Crop Bulletin, with charts, weekly. (Combined with Snow and Ice Bulletin, with charts, during the winter.)	25 c. a year.
Climatological Data, monthly for 42 separate sections, each section 5 c. a copy	50 c. a year.
Complete monthly number, 42 sections	35 c. each, $4 a year.
Kite data; 1917, Mo. Wea. Rev. Supplements 10 and 11; 1918, Mo. Wea. Rev. Supplements Nos. 12, 13, 14, and 15	25 c. each.
The daily weather map, with explanation (text and 4 charts)	5 c.
Explanation of the weather map (leaflet)	Free.
Instructions for cooperative observers, 6th ed. Circulars B and C combined	10 c.
Instructions for the installation and operation of class A evaporation stations. Circular L	10 c.
General classification of meteorological literature (leaflet). (Reprinted from Jan., 1919, Mo. Wea. Rev.)	Free.
Papers on meteorology as a subject for study. (Reprinted from Dec., 1918, Mo. Wea. Rev.)	Free.
Papers on aerological work. (Reprinted from Apr., 1919, Mo. Wea. Rev.)	Free.
Normal temperatures (daily): Are irregularities in the annual march of temperature persistent? [and] Literature concerning supposed recurrent irregularities in the annual march of temperature. (Reprinted from Aug., 1919, Mo. Wea. Rev.)	Free.
On the relation of atmospheric pressure, temperature, and density to altitude. (Reprinted from Mar., 1919, Mo. Wea. Rev.)	Free.
Modern methods of protection against lightning. (Farmers' Bull. No. 842)	Free.
Convectional clouds induced by forest fires. (Reprinted from Mar., 1919, Mo. Wea. Rev.)	Free.
Results of some empiric researches as to the general movements of the atmosphere. (Reprinted from June, 1919, Mo. Wea. Rev.)	Free.
Weather forecasting in the United States	$1.25
Weather forecasting and the structure of moving cyclones. (Reprinted from Feb., 1919, Mo. Wea. Rev.)	Free.
Periodical events and natural law as guides to agricultural research and practice. (Mo. Wea. Rev. Supplement No. 9)	25c.
Papers on agricultural meteorology. (Reprinted from May, 1919, Mo. Wea. Rev.)	Free.
Meteorological aspects of trans-Atlantic flights. (Separates from Feb., May, June, and Aug., 1919, Mo. Wea. Rev.)	Free.
Effect of winds and other weather conditions on the flight of airplanes. (Reprinted with associated papers from Aug., 1919, Mo. Wea. Rev.)	Free

As the surplus of MONTHLY WEATHER REVIEW, February, April, and July, 1919, is limited, recipients who do not care to retain their copies will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage.

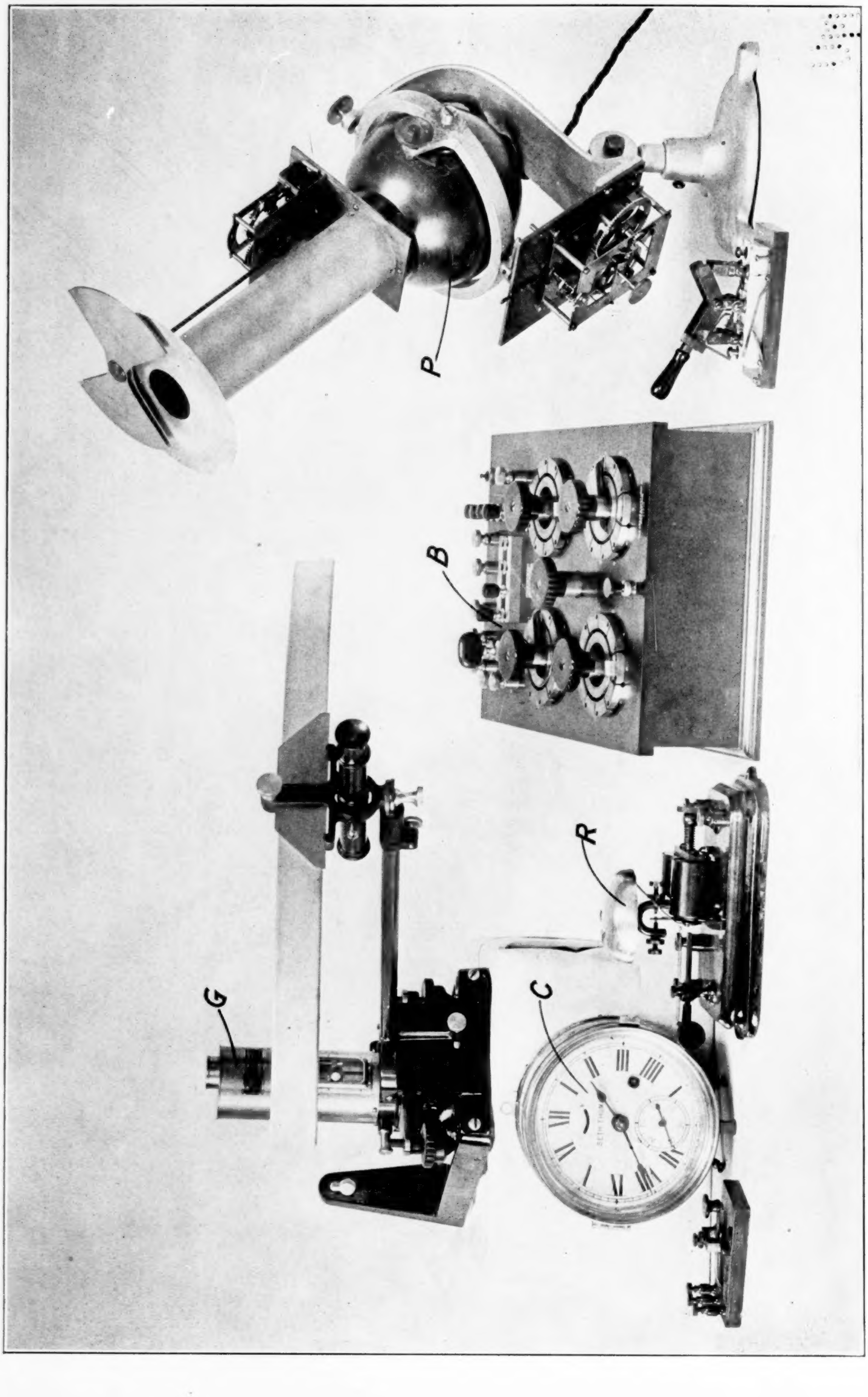

FIG. 1.—Marvin pyrheliometer and auxiliary apparatus.

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VARIATIONS IN THE TOTAL AND LUMINOUS SOLAR RADIATION WITH GEOGRAPHICAL POSITION IN THE UNITED STATES.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Weather Bureau, Washington, D. C., Jan. 2, 1920.]

SYNOPSIS.—The measurements of solar radiation intensity at normal incidence made at Washington, D. C., Madison, Wis., Lincoln, Nebr., and Santa Fe, N. Mex., have been utilized in determinations of the intensities for the Atlantic Coast States, the Plains States, and the Rocky Mountain plateau, at latitudes 30°, 36°, 42°, and 48° N., at hourly intervals, on the 21st day of each month. Corresponding determinations of the intensity of the radiation received on a horizontal surface, and of the total radiation per day, have been made from the vertical component of the normal intensities, and measurements by the Callendar recording pyrheliometer of the diffuse radiation received on a horizontal surface from the sky. The variations in the daily totals with altitude and with cloudiness have also been determined.

From the relation between the total solar or heat radiation and the visible or luminous radiation, determined by means of synchronous pyrheliometric and photometric measurements made at Mount Weather, Va., in 1913-14, the solar radiation intensities at normal incidence above described have been converted into illumination intensities at normal incidence, and on vertical surfaces facing S., SW., W., NW., N., NE., E., and SE. Also, the total illumination on a horizontal surface from the sun and sky has been determined for clear sky and completely overcast sky conditions.

Most of the results are shown in both tables and charts, the latter consisting of isopleths of heat or of luminous solar radiation, with hour angles of the sun as ordinates and days of the successive months as abscissas, except that the daily totals of radiation on a horizontal surface on the 21st of each month are shown by means of radiation isograms on outline maps of the United States.

The effect of surface slope on solar radiation intensities is briefly considered.

INTRODUCTION.

It is the purpose of this investigation to determine as accurately as possible with the data available, (1) the variation in direct solar radiation intensities with latitude, (2) the increase in intensity as we go westward from the Atlantic coast districts to the drier and more elevated central plains, (3) the total radiation received on a horizontal surface (direct solar, plus diffuse radiation from the sky), and (4) to reduce the total, or heat radiation as thus determined along certain parallels of latitude to luminous, or daylight intensity. There have been utilized in this investigation the radiation measurements made at Washington, D. C., since 1905; at Madison, Wis., since 1910; at Santa Fe, N. Mex., since 1912; and at Lincoln, Nebr., since 1915; and the measurements of the total solar, or heat radiation, and of luminous solar radiation or daylight illumination, made at Mount Weather, Va., during 1913 and 1914. The coordinates of these stations are as follows:

Washington, lat. 38° 56′ N.; long. 77° 05′ W.; alt. 418 ft. (127 m.).
Madison, lat. 43° 05′ N.; long. 89° 23′ W.; alt. 974 ft. (297 m.).
Lincoln, lat. 40° 50′ N.; long. 96° 41′ W.; alt. 1,225 ft. (373 m.).
Santa Fe, lat. 35° 41′ N.; long. 105° 57′ W.; alt. 7,037 ft. (2,145 m.).
Mount Weather, lat. 39° 04′ N.; long. 77° 53′ W.; alt. 1,772 ft. (540 m.).

The direct solar radiation measurements obtained at Washington prior to 1914 were made with an Ångström pyrheliometer; all others have been made with a Marvin pyrheliometer. They have been published in the Bulletin of the Mount Weather Observatory **3**:85-96, **5**:175-183, 302-303, and in the MONTHLY WEATHER REVIEW, 1914, **42**:648; 1915, **43**:112 (monthly thereafter).

THE MARVIN PYRHELIOMETER.

Figure 1, frontispiece, shows the Marvin pyrheliometer and the auxiliary apparatus employed in its standardization at the Weather Bureau. The pyrheliometer (P) consists of a silver disk, mounted inside a metal shell that is inclosed in the wooden bulb of the instrument, imbedded in which is an insulated nickel wire wound noninductively in the form of a thin disk. Its resistance is about 25 ohms. The front of the silver disk is blackened, and a beam of solar rays of known area is admitted to it through the diaphragmed tube. The bulb and tube have a clock-driven equatorial mounting, and on the tube is a mechanism for operating the shutter at the end of the tube, the circuit through the magnets of which is closed by the clock (C) at the end of each minute, thereby alternately opening or closing the shutter. A bell on the relay (R) is rung every 10 seconds by means of circuit breakers on the clock. The resistance coil of the pyrheliometer is in one arm of the Wheatstone bridge (B) and in the opposite arm are dials for varying the resistance to maintain approximately the bridge balance as the resistance of the pyrheliometric coil increases or decreases with heating or cooling. A high sensitivity galvanometer (G) is employed to measure small differences in resistance between the two arms of the bridge.

The pyrheliometers have been standardized by first carefully measuring the resistance of the coils at known temperatures, and then submitting them to the heating effect of an electric current of known strength and measuring the resulting change in resistance. There results a series of factors varying with the temperature, or resistance, of the coils, by means of which rates of change of resistance may be reduced to units of heat that have produced the observed changes of resistance, Dr. Paul D. Foote [1] of the United States Bureau of Standards has made a careful study of one of these pyrheliometers, and his results, which may be consulted for details of the methods followed, are confirmatory of the Weather Bureau determinations.

Comparisons of Marvin pyrheliometers with the Smithsonian Absolute pyrheliometer, through secondary Smithsonian Silver-disk pyrheliometers, have shown that the former read slightly the lower. For the sake of uniformity, the constants of the Marvin pyrheliometers have been increased to bring the instrumental readings into accord with the Smithsonian revised scale of pyrheliometry".[2]

[1] "Some characteristics of the Marvin pyrheliometer" Scientific papers of the Bureau of Standards, No. 323. Abstract in the MONTHLY WEATHER REVIEW for November, 1918, **46**: 499-500.

[2] "Smithsonian pyrheliometry revised," Abbot, C. G. and Aldrich, L. B. Smithsonian Misc. Col. Vol. 60, No. 18, 1913. See also Note on comparisons between pyrheliometers and on the difference between the Ångström Standard and the Smithsonian Standard, by Dr. Anders Ångström. This REVIEW, p. 798-799.

In measuring radiation intensities with the Marvin pyrheliometer the same auxiliary apparatus is employed as in the standardization of the instruments, except that a special bridge has been constructed, which has in the arm opposite that containing the pyrheliometer a single dial and a series of plugs in place of the four dials shown on the bridge in figure 1. Successive rates of increase and decrease of resistance with increase and decrease of the temperature of the coils during exposure to and shading from the sun, respectively, are measured during the 50-second intervals beginning with the 10-second signal by the relay bell, and ending with the 60-second signal.[3]

TOTAL SOLAR RADIATION.

There are six principal causes of variation in the solar radiation intensities at the surface of the earth, as follows:

(1) Variations in the amount of heat energy radiated from the sun, the intensity of which at the earth's mean solar diatance is called the solar constant. These are small, apparently nonperiodic variations, and need not be considered in this investigation.

(2) Variations in the earth's solar distance. Since the radiation intensity varies inversely as the square of this distance, we would expect it to be 7 per cent more intense with the earth in perihelion early in January than with the earth in aphelion early in July.

(3) Amount of water vapor in the atmosphere. In general, this decreases with latitude, altitude, and distance from the ocean, and increases with temperature.

(4) Dustiness or haziness of the atmosphere. This appears to be closely related to (3).

(5) The zenith distance of the sun, which is easily computed when we know the latitude of the place of observation, the sun's declination, and the apparent, or true solar time.

(6) Obviously, the radiation intensity will, in general, increase with altitude.

Generally speaking, in the northern hemisphere the water vapor content of the atmosphere increases at about the same time of year the earth's solar distance increases, so that with the sun at any given zenith distance the solar radiation intensity is much greater in winter than in summer, and in the early spring months than in the late fall. There is also a wide range in the intensities measured on different days in a given month, so that long series of measurements are necessary to establish monthly mean values. In this investigation such monthly means have been obtained from the mean of the weighted a. m. and p. m. normals that are derived from the "Monthly means" and "Departures from normal" given each month in the REVIEW from July, 1918, to June, 1919, inclusive, in my monthly summary of "Solar and sky radiation measurements," Table[4] Extreme accuracy would require that a. m. and p. m. radiation intensities be considered separately, but the character of the data available does not justify such refinement.

The radiation intensities measured at Washington with the sun at different zenith distances probably represent fairly well the intensities that would be measured anywhere in the Atlantic Coast States at elevations under 500 feet with similar atmospheric conditions as regards water vapor and haziness, and with the sun at corresponding zenith distances. Similarly, the measurements obtained at Madison and Lincoln probably represent fairly well places on the Central Plains between 1,000 and 1,500 feet above sea level; and those obtained at Santa Fe likewise represent radiation intensities on the Rocky Mountain Plateau at elevations of about 7,000 feet.

VARIATION DUE TO LATITUDE.

The radiation intensity at any hour of the day varies with the sun's altitude, or complement of the sun's zenith distance.[5] In Table 1 is given the altitude of the sun for each hour of apparent or true solar time from noon to sunset, on the 21st day of each month, for north latitudes 30°, 36°, 42°, and 48°. The altitudes are, of course, the same for corresponding hour angles of the sun from the meridian before noon. Table 2 gives the corresponding azimuths[6] of the sun, which, with the altitudes of Table 1, completely define the sun's position when referred to the horizontal system of coordinate circles. If we plot the logarithms of the monthly mean radiation intensities for the different stations above referred to against the corresponding air masses, m, (approximately the secant of the sun's zenith distance) we obtain slightly curved lines from which the logarithms of radiation intensities for air masses corresponding to any altitude of the sun, as, for instance, the altitudes of Table 1, may be read off.

TABLE 1.—*Solar altitudes.* 03

LATITUDE 30° N.

Date.	Sun's hour angle from meridian.															
	0		1		2		3		4		5		6		7	
	°	′	°	′	°	′	°	′	°	′	°	′	°	′	°	′
Dec. 21	36	33	34	33	29	12	21	12	12	04	0	20	.....		.....	
Jan. 21	40	06	38	03	32	21	23	56	13	42	2	19	.....		.....	
Feb. 21	49	29	47	00	40	16	30	44	19	33	7	25	.....		.....	
Mar. 21	60	16	57	01	48	47	37	56	25	48	13	05	0	08	.....	
Apr. 21	70	53	67	10	56	49	44	37	31	47	18	48	5	55	.....	
May 21	80	12	73	16	61	13	48	21	35	23	22	21	9	57	.....	
June 21	83	27	75	06	62	30	49	32	36	36	23	52	11	29	−0	23
July 21	80	29	73	27	61	21	48	28	35	30	22	39	10	05	.....	
Aug. 21	71	07	67	20	56	57	44	43	31	53	18	55	6	01	.....	
Sept. 21	60	42	57	25	49	07	38	12	26	03	13	19	0	21	.....	
Oct. 21	49	17	46	49	40	06	30	35	19	26	7	19	.....		.....	
Nov. 21	40	04	38	01	32	19	23	54	13	41	2	18	.....		.....	

[3] Prof. F. H. Bigelow in Supplement No. 1 to "Treatises on the Atmospheres of the Sun and the Earth," New York, 1919. p. 1, has erroneously classified the Marvin pyrheliometer with the Ångström pyrheliometer, which makes use of the static method of observation, instead of with the Smithsonian Silver-disk pyrheliometer, which makes use of the dynamic method of observation. Reference to the above description of the instrument, and to the paper by Dr. Foote already cited, will make clear Prof. Bigelow's error. However, with reference to his statement that the former (static) system is incapable of determining the true value of the "solar constant" of radiation, we need have no concern, since the method by which Professor Bigelow undertakes to compute the value of the "solar constant" from readings of the pyrheliometer is seriously in question (See *Science* June 21, 1918, NS. 47:609 and *Nature* (London) June 5, 1919, Vol. 103, p. 261.), while the accuracy of radiation measurements by such instruments as the Ångström and the Smithsonian pyrheliometers in the hands of competent observers is generally admitted. That the measurements by the Marvin pyrheliometer are equally accurate has been shown by frequent comparisons between the later and Smithsonian Silver-disk pyrheliometer No. 1, which is the property of the Weather Bureau, and which is itself frequently compared with the secondary pyrheliometers at the Smithsonian Institution.

[4] For Santa Fe, for the months October to March, inclusive, it will be necessary to consult the REVIEW for October, 1917, to March, 1918, inclusive.

[5] We may compute the sun's altitude from the equation

$$\sin a = \sin \phi \sin \delta + \cos h \cos \phi \cos \delta,$$

where a = solar altitude, δ = solar declination, h = hour angle of the sun from the meridian of the place = apparent solar time after noon, or 12 hours minus apparent solar time before noon, and ϕ = the latitude of the place of observation. The altitudes of Table 1 are true altitudes for the center of the sun and have been obtained from "Altitude, or Position Line Tables," by Fredrick Ball, London, 1st ed., 1907, 2d ed., 1910.

[6] We may compute the sun's azimuth from the equation $\sin \alpha = \frac{\cos \delta \sin h}{\cos a}$. The azimuths of Table 2 have been computed with the aid of Ball's Altitude or Position Line Tables, already referred to.

TABLE 1.—*Solar altitudes*—Continued.

LATITUDE 36° N.

Date.	0	1	2	3	4	5	6	7
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Dec. 21	30 33	28 53	24 08	16 55	7 53	......	......	......
Jan. 21	34 06	32 19	27 18	19 45	10 23	−0 11	......	......
Feb. 21	43 29	41 24	35 34	27 05	16 54	5 40	......	......
Mar. 21	54 16	51 29	44 42	35 05	24 02	12 15	0 09	......
Apr. 21	65 53	62 22	53 47	42 55	31 08	19 02	6 58	......
May 21	74 12	69 27	59 22	47 43	35 38	23 33	11 43	0 22
June 21	77 23	71 57	61 15	49 21	37 14	25 13	13 31	1 46
July 21	74 29	69 41	59 33	47 52	35 47	23 42	11 52	0 33
Aug. 21	66 07	62 33	53 56	43 03	31 14	19 09	7 05	......
Sept. 21	54 42	52 03	45 03	35 24	24 18	12 30	0 25	......
Oct. 21	43 17	41 12	35 24	26 56	16 46	5 33	......	......
Nov. 21	34 04	32 17	27 16	19 43	10 22	−0 12	......	......

LATITUDE 42° N.

Date.	0	1	2	3	4	5	6	7
Dec. 21	24 33	23 06	18 55	12 28	4 17	......	......	......
Jan. 21	28 06	26 34	22 11	15 27	6 59	......	......	......
Feb. 21	37 29	35 43	30 42	23 14	14 05	3 50	......	......
Mar. 21	48 16	46 08	40 18	31 56	22 02	11 57	0 11	......
Apr. 21	59 53	57 09	50 06	40 40	30 05	19 01	7 55	......
May 21	68 12	64 47	56 37	46 24	35 26	24 18	13 22	2 54
June 21	71 27	67 41	59 04	48 35	37 31	26 25	15 34	5 14
July 21	68 29	65 03	56 50	46 36	35 37	24 29	13 33	3 06
Aug. 21	60 07	57 23	50 21	40 52	30 15	19 11	8 05	......
Sept. 21	48 42	46 31	40 42	32 18	22 21	11 35	0 28	......
Oct. 21	37 17	35 29	30 32	23 04	13 55	3 42	......	......
Nov. 21	28 04	26 32	22 09	15 23	6 58	......	......	......

LATITUDE 48° N.

Date.	0	1	2	3	4	5	6	7
Dec. 21	18 33	17 17	13 39	7 58	0 38	......	......	......
Jan. 21	22 06	20 47	16 59	11 05	3 32	......	......	......
Feb. 21	31 29	30 00	25 45	19 34	11 10	2 00	......	......
Mar. 21	42 16	40 31	35 40	28 29	19 47	10 10	0 12	......
Apr. 21	53 53	51 46	46 04	38 02	28 43	18 49	8 48	......
May 21	62 12	59 40	53 10	44 29	34 47	24 47	14 52	5 25
June 21	65 27	62 44	55 53	46 56	37 10	27 06	17 16	7 53
July 21	62 29	59 57	53 25	44 42	35 00	24 59	15 05	5 37
Aug. 21	54 07	51 59	46 16	38 12	28 53	18 59	8 58	......
Sept. 21	42 42	40 56	36 04	28 52	20 09	10 31	0 32	......
Oct. 21	31 17	29 48	25 34	19 23	10 59	1 49	......	......
Nov. 21	22 04	20 45	16 57	11 03	3 30	......	......	......

TABLE 2.—*Solar azimuths.*

LATITUDE 30° N.

Date.	Declination.	0	1	2	3	4	5	6	7	Sunrise or sunset.
	° ′	°	°	°	°	°	°	°	°	°
Dec. 21	−23 27	0	17	32	44	54	60	......	......	62
Jan. 21	−19 54	0	18	34	47	57	65	......	......	66
Feb. 21	−10 31	0	22	40	54	65	73	......	......	77
Mar. 21	0 16	0	28	49	64	74	83	90	......	91
Apr. 21	11 53	0	41	63	76	86	93	100	......	104
May 21	20 12	0	58	77	87	95	101	108	......	114
June 21	23 27	0	67	84	92	99	104	111	118	118
July 21	20 29	0	58	77	87	95	101	108	......	114
Aug. 21	12 07	0	41	64	77	86	93	101	......	104
Sept. 21	0 42	0	29	50	64	74	83	91	......	91
Oct. 21	−10 43	0	22	40	54	65	73	......	......	77
Nov. 21	−19 56	0	18	34	47	57	65	......	......	66

LATITUDE 36° N.

Date.	Declination.	0	1	2	3	4	5	6	7	Sunrise or sunset.
Dec. 21	−23 27	0	16	30	43	54	......	......	......	60
Jan. 21	−19 54	0	17	32	45	56	65	......	......	64
Feb. 21	−10 31	0	20	37	51	63	73	......	......	76
Mar. 21	0 16	0	25	45	60	72	81	90	......	91
Apr. 21	11 53	0	33	55	71	82	91	100	......	106
May 21	20 12	0	44	67	81	90	99	107	115	116
June 21	23 27	0	50	72	85	94	102	109	118	120
July 21	20 29	0	44	68	81	91	99	107	115	116
Aug. 21	12 07	0	33	56	72	82	91	100	......	106
Sept. 21	0 42	0	25	45	61	72	82	91	......	92
Oct. 21	−10 43	0	20	37	51	63	73	......	......	76
Nov. 21	−19 56	0	17	32	45	57	65	......	......	64

TABLE 2.—*Solar azimuths*—Continued.

LATITUDE 42° N.

Date.	Declination.	0	1	2	3	4	5	6	7	Sunrise or sunset.
	° ′	°	°	°	°	°	°	°	°	°
Dec. 21	−23 27	0	15	29	42	53	......	......	......	57
Jan. 21	−19 54	0	17	30	44	55	......	......	......	62
Feb. 21	−10 31	0	18	35	50	62	72	......	......	75
Mar. 21	0 16	0	22	41	56	69	80	90	......	91
Apr. 21	11 53	0	28	50	66	78	89	99	......	107
May 21	20 12	0	35	58	74	86	96	105	115	119
June 21	23 27	0	39	63	78	89	99	108	117	123
July 21	20 29	0	35	59	75	86	96	106	115	119
Aug. 21	12 07	0	28	50	66	79	89	99	......	107
Sept. 21	0 42	0	22	41	56	69	80	91	......	92
Oct. 21	−10 43	0	18	35	49	61	72	......	......	75
Nov. 21	−19 56	0	17	30	44	55	......	......	......	62

LATITUDE 48° N.

Date.	Declination.	0	1	2	3	4	5	6	7	Sunrise or sunset.
Dec. 21	−23 27	0	14	28	41	52	......	......	......	53
Jan. 21	−19 54	0	15	30	43	55	......	......	......	58
Feb. 21	−10 31	0	17	33	47	60	72	......	......	73
Mar. 21	0 16	0	20	38	53	67	79	90	......	91
Apr. 21	11 53	0	24	45	62	75	87	98	......	109
May 21	20 12	0	28	52	68	82	93	104	114	122
June 21	23 27	0	31	55	72	85	95	106	117	127
July 21	20 29	0	29	52	69	82	93	104	115	122
Aug. 21	12 07	0	24	45	62	75	87	98	......	109
Sept. 21	0 42	0	20	38	54	67	79	91	......	92
Oct. 21	−10 43	0	17	33	47	60	72	......	......	73
Nov. 21	−19 56	0	15	30	43	55	......	......	......	58

TABLE 3.—*Relation between radiation intensities and the atmospheric water vapor pressure at the earth's surface.*

e.	Washington, D. C.			Madison, Wis.			Santa Fe, N. Mex.		
	Q_2	ΔQ	$\frac{\Delta Q}{Q_2}$	Q_2	ΔQ	$\frac{\Delta Q}{Q_2}$	Q_2	ΔQ	$\frac{\Delta Q}{Q_2}$
mm.	*cal.*	*cal.*	*Per cent.*	*cal.*	*cal.*	*Per cent.*	*cal.*	*cal.*	*Per cent.*
1.0	1.208	......	......	1.385	......	......	1.453	......	......
2.0	1.180	0.028	2.3	1.348	0.037	2.7	1.418	0.035	2.4
3.0	1.154	26	2.2	1.315	33	2.5	1.385	33	2.3
4.0	1.129	25	2.2	1.284	31	2.4	1.355	30	2.2
5.0	1.104	25	2.2	1.255	29	2.3	1.327	28	2.1
6.0	1.081	23	2.1	1.230	25	2.0	1.301	26	2.0
7.0	1.058	23	2.1	1.205	25	2.0	1.276	25	1.9
8.0	1.035	23	2.2	1.183	22	1.8	1.254	22	1.7
9.0	1.014	21	2.0	1.161	22	1.9	1.233	21	1.7
10.0	0.994	20	2.0	1.139	22	1.9	1.212	21	1.7
11.0	0.974	20	2.0	1.118	21	1.9	1.192	20	1.7
12.0	0.954	20	2.1	1.096	22	2.0	......	......	......
13.0	0.936	18	1.9	1.075	21	1.9	......	......	......
14.0	0.918	18	1.9	1.053	22	2.1	......	......	......
15.0	0.900	18	2.0	1.032	21	2.0	......	......	......
16.0	0.883	17	1.9	0.970	62	6.0	......	......	......
17.0	0.867	16	1.8	0.905	65	6.7	......	......	......
18.0	......	......	......	0.840	65	7.2	......	......	......

WATER VAPOR CORRECTION.

The radiation intensities must next be corrected for variation in the water vapor content of the atmosphere with latitude. This correction has been determined as follows:

(1) Table 3 shows the relation between radiation intensities Q_2 and the atmospheric water vapor pressure, e, at Washington, Madison, and Santa Fe, with the sun at zenith distance 60°, $m=2$. The radiation intensities have been reduced to mean solar distance of the earth. It will be seen that in general an increase of 1 mm. in the water vapor pressure decreases the radiation intensity by 2 per cent. This result is in accord with that obtained by Gorczyński and others.[7] A previous investi-

[7] Gorczyński, Ladislas. Sur La Marche Annuelle de l'intensité du rayonnement Solaire a Varsovie. Varsovie, 1906. Valeurs pyrhéliometriques, et les sommes d'insolation à Varsovie, 1901-1913. Varsovie, 1914.
Westman, J. Mesures de l'intensité de la radiation solaire faites à Upsala en 1901. Upsala. 1907. 55p. f°. (Kungl. Svenska vetenskapsakademiens handlingar. Bd. 2. No. 4. p. 26.)

gation[8] by the writer had shown that absorption of radiation by water vapor would lead us to expect a decrease of intensity of only about 1 per cent per mm. increase in e. The earlier comparisons, however, were confined to days when polarization of skylight indicated equal intensities of scattered sunlight. In this present case the greater decrease in radiation with increase in vapor pressure must be attributed to the fact that generally there is increased haziness, and, therefore, increased scattering of the sun's rays, with increase in vapor pressure, partly, perhaps, on account of the hygroscopic character of the dust and other particles in the atmosphere.

(2) From the plotted logarithms of the monthly mean radiation intensities already referred to, it is found that the atmospheric transmission coefficient[9] is diminished about 0.6 per cent for an increase in e of 1 mm. Therefore the total effect of water vapor pressure upon radiation may be expressed approximately by the equation

$$Q'_m = Q_m(0.98^{\Delta e} \times 0.994,^{m-2} \quad (1)$$

where Q_m is the monthly mean radiation intensity for air mass m at a given station and Q'_m is the intensity at another locality under similar climatic conditions, except that the value of e is Δe millimeters greater.

In Table 4 are given the monthly means of water vapor pressure for Washington, Madison, Lincoln, and Santa Fe, and for group of stations along the thirtieth, thirty-sixth, forty-second, and forty-eighth parallels of latitude.[10]

TABLE 4.—*Monthly mean water vapor pressure.*

EASTERN STATES.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Washington....	3.40	3.48	4.52	6.35	10.21	14.20	16.33	15.67	12.83	8.31	5.31	3.81
Lat. 30°.	8.08	8.90	10.59	12.82	15.98	19.56	20.83	20.72	18.62	13.86	10.54	8.67
Δe.......	+4.68	+5.43	+6.07	+6.47	+5.77	+5.36	+4.50	+5.05	+5.79	+5.55	+5.23	+4.86
Lat. 36°.	4.54	4.83	6.07	7.94	11.67	15.60	17.52	17.07	13.90	9.26	6.28	4.96
Δe.......	+1.14	+1.35	+1.55	+1.59	+1.46	+1.40	+1.19	+1.40	+1.07	+0.95	+0.97	+1.15
Lat. 42°.	2.67	2.68	3.64	5.27	8.22	11.93	13.94	13.19	10.77	7.18	4.64	3.27
Δe.......	−0.73	−0.80	−0.88	−1.08	−1.99	−2.27	−2.39	−2.48	−2.06	−1.13	−0.67	−0.54

CENTRAL STATES.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Madison.	2.29	2.18	3.53	5.18	8.52	11.87	13.31	13.12	10.76	6.67	4.27	2.79
Lincoln..	2.60	2.56	3.92	5.70	9.12	12.68	14.25	14.28	10.86	7.07	4.29	2.81
Lat. 30°.	5.10	5.61	6.87	8.84	11.51	13.81	15.86	16.15	13.69	9.67	6.81	5.51
$\Delta_L e$......	+2.50	+3.50	+2.95	+3.14	+2.39	+1.13	+1.61	+1.87	+2.83	+2.60	+2.52	+2.70
Lat. 36°.	3.40	3.58	4.91	6.18	10.85	14.32	15.51	14.93	11.92	8.02	5.22	3.87
$\Delta_L e$......	+0.80	+1.02	+0.99	+0.48	+1.73	+1.64	+1.26	+0.65	+1.06	+0.95	+0.93	+1.06
Lat. 42°.	1.93	2.05	3.29	5.32	8.21	12.17	14.03	13.14	9.55	6.11	3.48	2.44
Δe.......	−0.51	−0.32	−0.43	−0.12	−0.61	−0.51	−0.22	−1.14	−1.31	−0.96	−0.81	−0.36
Lat. 48°..	1.34	1.33	2.31	4.13	6.18	9.11	10.99	10.10	7.54	5.10	2.89	1.9
Δe.......	−1.10	−1.04	−1.41	−1.31	−2.64	−3.57	−3.26	−4.27	−3.32	−1.97	−1.40	−0.89

CENTRAL PLATEAU.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Santa Fe	2.13	2.44	2.64	3.12	4.19	5.51	8.08	8.05	6.15	4.17	2.87	2.21
Lat. 42°.	2.42	2.58	3.09	3.68	4.87	5.99	6.77	6.56	4.93	4.09	3.11	2.45
Lat. 42° × 0.8.....	1.94	2.06	2.47	2.94	3.90	4.79	5.42	5.25	3.94	3.27	2.49	1.96
Δe.......	−0.19	−0.38	−0.17	−0.18	−0.29	−0.72	−2.66	−2.80	−2.21	−0.90	−0.38	−0.25

[8] Some causes of variation in the polarization of skylight. Jr. Franklin Inst., Apr. 1911, p. 339.

[9] Log. a=log. Q_m-log. Q_{m-1}, where a is the atmospheric transmission coefficient and m is any air mass.

[10] These data have been taken from W. B. Bulletin W and REVIEW Supplement No. 6 for the following stations:

Lat. 30°: Gulf Coast, Galveston, Tex.; Jacksonville, Fla.; Mobile, Ala.; and New Orleans, La. Southern Plains, Abilene, Tex.; San Antonio, Tex.; Yuma, Ariz.

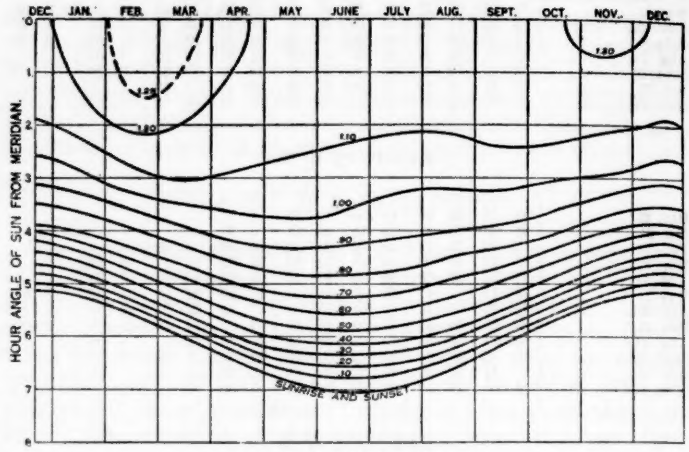
Lat. 36°: Eastern U. S., Chattanooga, Tenn.; Charlotte, N. C.; Knoxville, Tenn.; Memphis, Tenn.; Nashville, Tenn.; Norfolk, Va.; Raleigh, N. C. Central Plains, Amarillo, Tex.; Fort Smith, Ark.; Oklahoma, Okla.

Lat. 42°: Northeastern U. S., Albany, N. Y.; Boston, Mass.; Buffalo, N. Y.; Chicago, Ill.; Cleveland, Ohio; Detroit, Mich.; Erie, Pa.; New Haven, Conn.; Sandusky, Ohio; Toledo, Ohio. Central Plains, Davenport, Iowa; Des Moines, Iowa; Dubuque, Iowa; North Platte, Nebr.; Omaha, Nebr.; Valentine, Nebr.; Yankton, S. Dak. Central Plateau, Cheyenne, Wyo.; Lander, Wyo.; Pocatello, Idaho; Salt Lake City, Utah; Winnemucca, Nev.

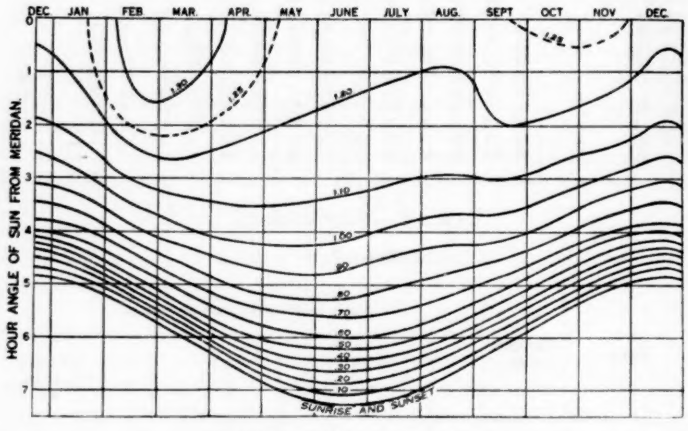
Lat. 48°: Northern Plains, Devils Lake, N. Dak.; Duluth, Minn.; Havre, Mont.; Houghton, Mich.; Moorhead, Minn.; Williston, N. Dak.

In the table, Δe for lat. 30°, on the Gulf Coast, for lat. 36°, in the States east of the Mississippi, and for lat. 42° in the northeastern States, is the average excess of the monthly mean water vapor pressure for the respective latitudes over the monthly means for Washington; and this value has been used in equation (1) to determine the water vapor correction.

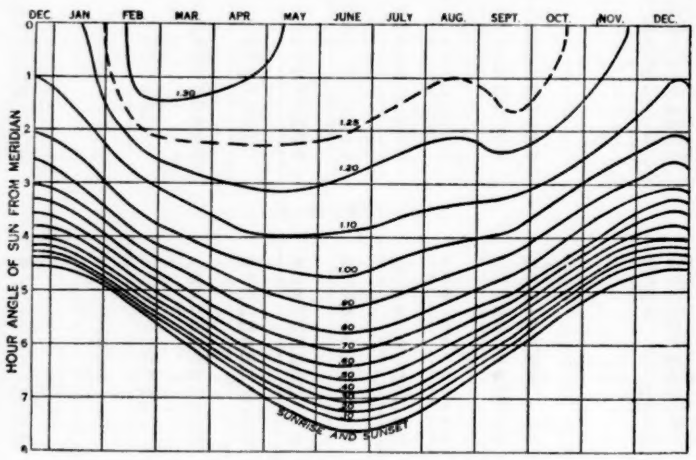
Applying the water vapor correction as above determined to the radiation intensities for latitudes 30°, 36°, and 42°, as derived from the monthly means for Wash-



(*a*), Latitude 30°N. (Gulf Coast).

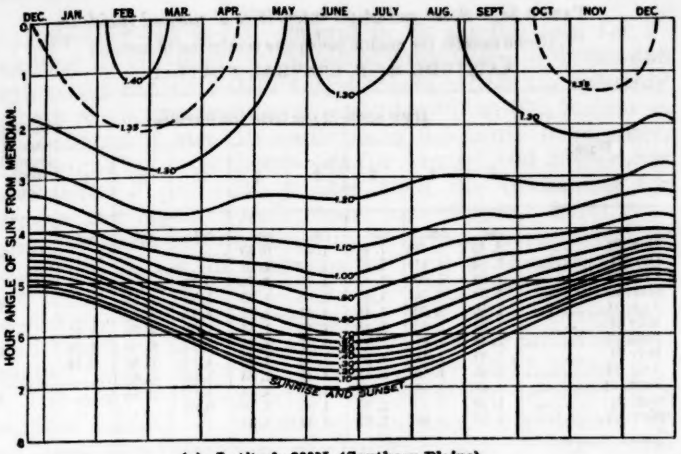


(*b*), Latitude 36°N. (Eastern States).

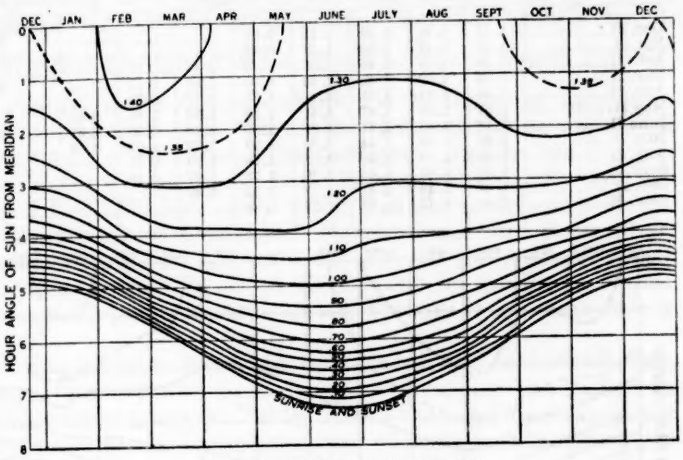


(*c*), Latitude 42°N. (Northeastern States).

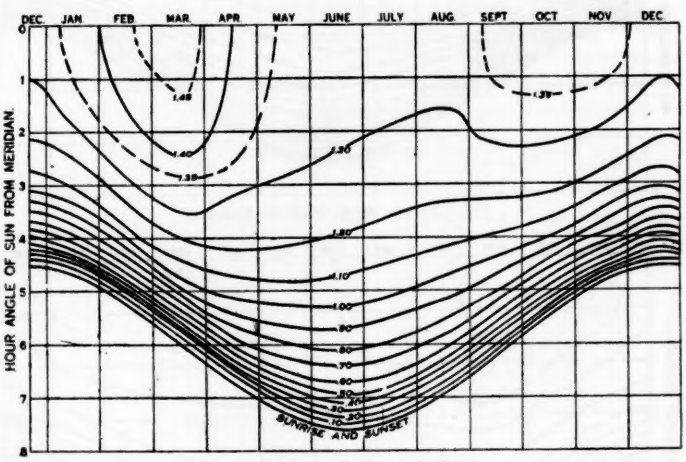
FIGURE 2.—Solar radiation intensity at normal incidence. (Gram calories per minute per square centimeter.)



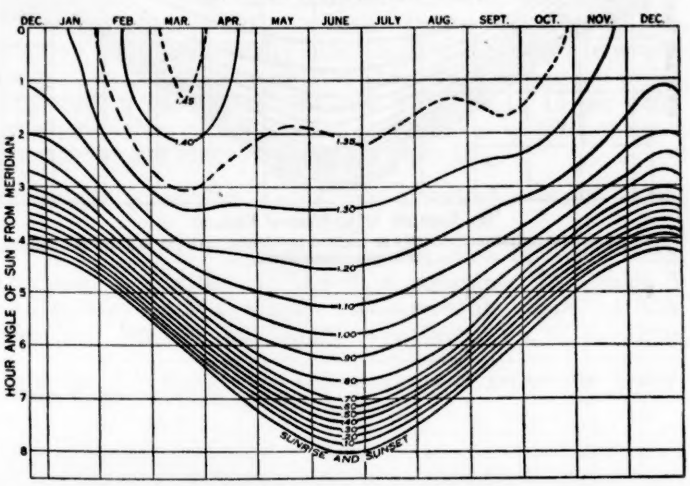
(a), Latitude 30°N. (Southern Plains).



(b), Latitude 36°N. (Central Plains).



(c), Latitude 42°N. (Central Plains).



(d), Latitude 48°N. (Northern Plains).

FIGURE 3.—Solar radiation intensity at normal incidence. (Gram calories per minute per square centimeter.)

ington, the intensities of Table 5a and figure 2 are obtained.

A comparison of radiation intensities for lat. 42° derived from Madison and Lincoln measurements indicates that the increased tendency to cloud formation, perhaps due to the presence of numerous lakes in the vicinity of Madison, depresses the radiation intensity at that station during the warm part of the year (May to November), when the lakes are free from ice. During the cold months (December to April), the effect of the lakes is not apparent. During these latter months, therefore, the mean of the radiation intensity and the vapor pressure at these two stations has been employed in determining the radiation intensity and the vapor pressure in the Plains States at lat. 42° and 48°, and the data for Lincoln for the remainder of the year. The Lincoln data have also been employed in determining the radiation intensities at lat. 36° and 30° in the Plains States. The intensities thus determined are given in Table 5b and figure 3.

TABLE 5a.—*Solar radiation intensity at normal incidence.*

(Gram-calories per minute per square centimeter of surface.)

LATITUDE 30° N. GULF COAST.

Date.	Hour angle of sun from meridian.								Percentage of possible daily total.
	0	1	2	3	4	5	6	7	
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	
Dec. 21	1.19	1.16	1.09	0.93	0.67	0.12	......	......	......
Jan. 21	1.23	1.21	1.15	0.99	0.72	0.23	......	......	......
Feb. 21	1.29	1.28	1.22	1.10	0.87	0.57	......	......	......
Mar. 21	1.26	1.24	1.19	1.10	0.90	0.61	0.11	......	......
Apr. 21	1.20	1.19	1.15	1.09	0.96	0.71	0.38	......	......
May 21	1.17	1.16	1.12	1.05	0.94	0.74	0.41	......	......
June 21	1.16	1.15	1.12	1.06	0.95	0.76	0.47	......	......
July 21	1.19	1.18	1.14	1.08	0.96	0.77	0.48	......	......
Aug. 21	1.16	1.15	1.11	1.03	0.89	0.67	0.35	......	......
Sept. 21	1.19	1.17	1.14	1.05	0.88	0.58	0.11	......	......
Oct. 21	1.20	1.18	1.13	1.01	0.80	0.49	......	......	......
Nov. 21	1.22	1.19	1.12	0.98	0.71	0.22	......	......	......
LATITUDE 36° N. EASTERN U. S.									
Dec. 21	1.22	1.18	1.09	0.92	0.62	......	......	......	46
Jan. 21	1.25	1.22	1.15	0.99	0.70	......	......	......	......
Feb. 21	1.34	1.33	1.27	1.14	0.91	0.50	......	......	......
Mar. 21	1.33	1.31	1.26	1.16	0.99	0.70	0.11	......	53
Apr. 21	1.28	1.27	1.22	1.17	1.04	0.82	0.50	......	......
May 21	1.23	1.22	1.19	1.12	1.02	0.85	0.59	0.11	......
June 21	1.23	1.22	1.19	1.13	1.02	0.86	0.60	0.13	50
July 21	1.24	1.23	[illegible]	1.13	1.03	0.86	0.61	0.11	......
Aug. 21	1.21	1.19	1.15	1.08	0.95	0.75	0.45	......	......
Sept. 21	1.25	1.24	1.20	1.12	0.95	0.67	0.11	......	51
Oct. 21	1.26	1.24	1.18	1.06	0.84	0.48	......	......	......
Nov. 21	1.26	1.23	1.16	0.99	0.70	......	......	......	......
LATITUDE 42° N. NORTHEASTERN U. S.									
Dec. 21	1.14	1.10	1.01	0.81	0.41	......	......	......	43
Jan. 21	1.21	1.18	1.10	0.93	0.61	......	......	......	......
Feb. 21	1.34	1.33	1.25	1.12	0.95	0.41	......	......	......
Mar. 21	1.34	1.32	1.27	1.17	1.01	0.73	0.12	......	53
Apr. 21	1.32	1.30	1.27	1.21	1.09	0.89	0.58	......	......
May 21	1.29	1.28	1.24	1.18	1.10	0.94	0.73	0.20	......
June 21	1.29	1.28	1.25	1.19	1.09	0.96	0.75	0.36	53
July 21	1.29	1.28	1.24	1.18	1.11	0.95	0.75	0.20	......
Aug. 21	1.26	1.25	1.21	1.14	1.02	0.83	0.48	......	......
Sept. 21	1.29	1.27	1.24	1.14	0.98	0.72	0.11	......	51
Oct. 21	1.25	1.24	1.18	1.04	0.81	0.35	......	......	......
Nov. 21	1.21	1.18	1.10	0.92	0.55	......	......	......	......

TABLE 5b.—*Solar radiation intensity at normal incidence.*

(Gram-calories per minute per square centimeter of surface.)

LATITUDE 30° N. SOUTHERN PLAINS.

Date.	Hour angle of sun from the meridian.								Percentage of possible daily total.
	0	1	2	3	4	5	6	7	
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	
Dec. 21	1.35	1.34	1.29	1.17	0.91	0.15			
Jan. 21	1.38	1.37	1.32	1.22	0.98	0.29			
Feb. 21	1.42	1.41	1.36	1.29	1.12	0.69			
Mar. 21	1.39	1.38	1.34	1.29	1.16	0.85	0.13		
Apr. 21	1.35	1.34	1.31	1.25	1.14	0.89	0.49		
May 21	1.29	1.28	1.26	1.21	1.15	0.93	0.58		
June 21	1.32	1.31	1.29	1.24	1.15	0.98	0.71		
July 21	1.31	1.30	1.28	1.23	1.16	0.94	0.62		
Aug. 21	1.29	1.28	1.25	1.19	1.08	0.87	0.51		
Sept. 21	1.33	1.32	1.28	1.21	1.06	0.74	0.12		
Oct. 21	1.36	1.35	1.31	1.23	1.05	0.62			
Nov. 21	1.38	1.37	1.32	1.22	0.98	0.29			

LATITUDE 36° N. CENTRAL PLAINS.

Date.	0	1	2	3	4	5	6	7	Percentage of possible daily total.
Dec. 21	1.35	1.33	1.27	1.12	0.76				54
Jan. 21	1.38	1.37	1.32	1.19	0.91				
Feb. 21	1.44	1.43	1.38	1.31	1.12	0.63			
Mar. 21	1.41	1.40	1.37	1.31	1.18	0.88	0.13		59
Apr. 21	1.39	1.38	1.35	1.30	1.19	0.97	0.59		
May 21	1.31	1.30	1.28	1.22	1.13	0.96	0.80	0.13	
June 21	1.30	1.30	1.28	1.23	1.15	0.99	0.83	0.17	57
July 21	1.32	1.31	1.29	1.23	1.14	0.97	0.81	0.14	
Aug. 21	1.31	1.30	1.27	1.21	1.11	0.89	0.58		
Sept. 21	1.35	1.34	1.30	1.23	1.07	0.76	0.12		56
Oct. 21	1.37	1.36	1.32	1.23	1.03	0.56			
Nov. 21	1.38	1.36	1.31	1.19	0.90				

LATITUDE 42° N. CENTRAL PLAINS.

Date.	0	1	2	3	4	5	6	7	Percentage of possible daily total.
Dec. 21	1.32	1.30	1.22	1.05	0.52				49
Jan. 21	1.37	1.35	1.30	1.15	0.75				
Feb. 21	1.45	1.44	1.39	1.30	1.09	0.48			
Mar. 21	1.47	1.46	1.43	1.37	1.24	0.95	0.13		61
Apr. 21	1.39	1.38	1.36	1.31	1.23	1.05	0.72		
May 21	1.34	1.33	1.31	1.26	1.19	1.03	0.79	0.28	
June 21	1.34	1.33	1.31	1.27	1.19	1.06	0.84	0.51	58
July 21	1.33	1.32	1.30	1.26	1.18	1.03	0.78	0.25	
Aug. 21	1.32	1.31	1.29	1.23	1.13	0.94	0.63		
Sept. 21	1.37	1.36	1.32	1.24	1.09	0.78	0.12		59
Oct. 21	1.37	1.36	1.33	1.23	1.00	0.44			
Nov. 21	1.37	1.35	1.29	1.13	0.76				

LATITUDE 48° N. NORTHERN PLAINS.

Date.	0	1	2	3	4	5	6	7	Percentage of possible daily total.
Dec. 21	1.23	1.21	1.10	0.81	0.14				
Jan. 21	1.32	1.29	1.21	1.02	0.47				
Feb. 21	1.42	1.41	1.35	1.27	1.01	0.32			
Mar. 21	1.48	1.46	1.43	1.36	1.23	0.92	0.14		
Apr. 21	1.40	1.39	1.37	1.33	1.24	1.08	0.82		
May 21	1.36	1.35	1.33	1.30	1.22	1.09	0.87	0.52	
June 21	1.39	1.38	1.36	1.33	1.26	1.15	0.96	0.71	
July 21	1.38	1.38	1.35	1.31	1.24	1.10	0.90	0.54	
Aug. 21	1.37	1.36	1.33	1.29	1.19	1.02	0.80		
Sept. 21	1.39	1.37	1.34	1.25	1.10	0.79	0.13		
Oct. 21	1.36	1.34	1.30	1.19	0.91	0.22			
Nov. 21	1.31	1.28	1.21	1.01	0.47				

The latitude of Santa Fe (35° 41′) differs so little from 36° that the vapor pressure for that station has been employed for lat. 36° on the Plateau. For lat. 42° the vapor pressures determined at stations averaging about 5,000 feet have been reduced to the 7,000-foot level by the use of Hann's equation,[11] the factor in this case being 0.8. The resulting radiation intensities are given in Table 5c and figure 4.

[11] Smithsonian Meteorological Tables, 4th edit., 1918, p. 194.

TABLE 5c.—*Solar radiation intensities at normal incidence.*

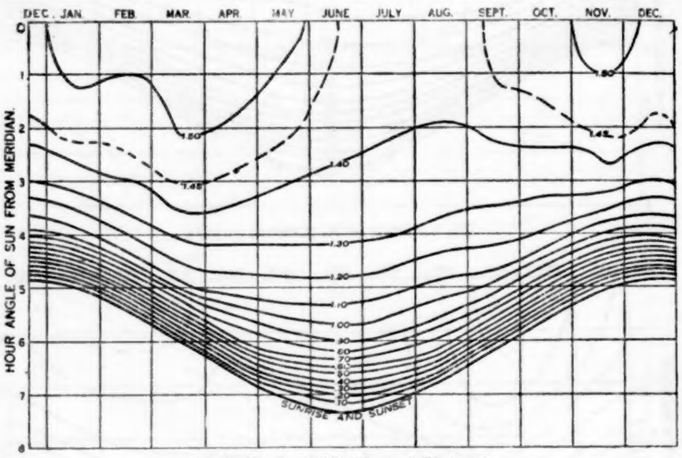
(Gram calories per minute per square centimeter of surface.)

LATITUDE 36° N. CENTRAL PLATEAU.

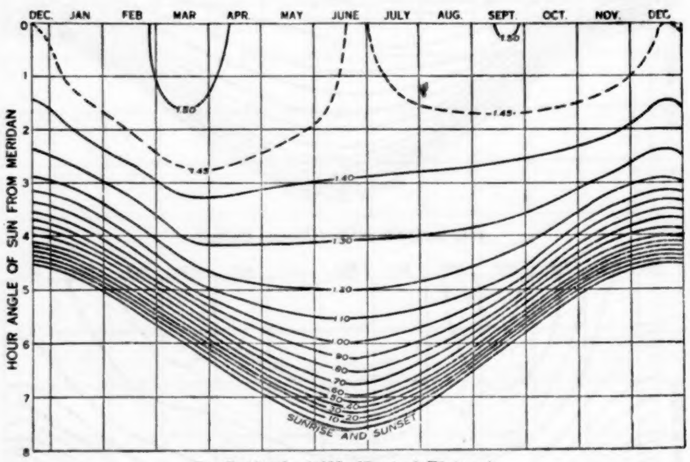
Date.	Hour angle of sun from the meridian.								Percentage of possible daily total.
	0	1	2	3	4	5	6	7	
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	
Dec. 21	1.49	1.48	1.44	1.30	0.93				62
Jan. 21	1.52	1.51	1.47	1.37	1.07				
Feb. 21	1.51	1.50	1.47	1.40	1.24	0.70			
Mar. 21	1.54	1.54	1.51	1.46	1.36	1.11	0.16		67
Apr. 21	1.50	1.50	1.46	1.41	1.32	1.16	0.70		
May 21	1.51	1.50	1.48	1.43	1.34	1.22	1.03	0.15	
June 21	1.42	1.41	1.39	1.37	1.29	1.17	0.93	0.21	60
July 21	1.41	1.41	1.39	1.34	1.26	1.15	0.85	0.14	
Aug. 21	1.41	1.40	1.37	1.32	1.23	1.07	0.67		
Sept. 21	1.47	1.46	1.42	1.36	1.24	1.02	0.15		64
Oct. 21	1.49	1.48	1.43	1.35	1.18	0.61			
Nov. 21	1.52	1.50	1.47	1.37	1.07				

LATITUDE 42° N. CENTRAL PLATEAU.

Date.	0	1	2	3	4	5	6	7	Percentage of possible daily total.
Dec. 21	1.45	1.43	1.36	1.18	0.60				58
Jan. 21	1.49	1.47	1.42	1.27	0.87				
Feb. 21	1.49	1.49	1.45	1.36	1.19	0.49			
Mar. 21	1.53	1.52	1.49	1.44	1.35	1.08	0.15		63
Apr. 21	1.49	1.48	1.45	1.41	1.32	1.17	0.79		
May 21	1.51	1.50	1.47	1.42	1.35	1.24	1.08	0.40	
June 21	1.44	1.43	1.41	1.36	1.30	1.18	0.96	0.61	63
July 21	1.47	1.46	1.44	1.39	1.33	1.23	1.01	0.40	
Aug. 21	1.45	1.44	1.42	1.38	1.29	1.15	0.77		
Sept. 21	1.51	1.48	1.44	1.39	1.28	1.07	0.15		65
Oct. 21	1.47	1.45	1.41	1.33	1.15	0.40			
Nov. 21	1.49	1.47	1.42	1.28	0.86				



(*a*), Latitude 36°N. (Central Plateau).



(*b*), Latitude 42°N. (Central Plateau).

FIGURE 4.—Solar radiation intensity at normal incidence. (Gram calories per minute per square centimeter.)

Equation (1) is not general in its application, for if applied to Washington radiation intensities to determine intensities for the Pacific Coast States, where the monthly means of vapor pressure for latitudes 36° to 42°, inclusive, lie between 6 mm. in winter and 9.5 mm. in summer, the computed noon intensities for August and September are about 5 per cent greater than the intensities for March and April, which seems improbable. More consistent values are obtained by applying to the Atlantic coast intensities for latitudes 36° and 42°, respectively, a correction of about 0.01 Δe, or -3 per cent for January and February, -2 per cent for November, December, and March, $+2$ per cent for May, $+4$ per cent for September, and $+6$ per cent for June, July, and August.

The daily totals of direct solar radiation received on a surface normal to the sun's rays may be obtained by plotting the intensities of Table 5 against the corresponding hour angles of the sun, integrating the areas under the curves, and multiplying the results by 2. The possible daily total is found by the equation $\Sigma I_0 = \frac{I_0 t}{R^2}$ where I_0 is the solar constant, t is the length of the day in minutes, and R is the earth's solar distance expressed in terms of its mean solar distance. In the last column of Table 5 is given the ratio between the "Daily totals," and the "Possible daily totals" as above determined, for the months of December, March, June, and September, and latitudes 36° N., and 42° N. In the Atlantic Coast States the ratio is about 50 per cent, in the Plains States about 57 per cent, and on the Plateau it is about 63 per cent.

The water vapor correction for lat. 30° as derived from equation (1) may be too large. Possibly the radiation intensities given in Table 5a for that latitude are 5 per cent too low. The percentage of error in the remainder of Table 5 must be small, however.

TABLE 6.—*Noon radiation intensities.*

(Gram-calories per minute per square centimeter of normal surface.)

Date.	Washington.			Madison.			Lincoln.			Santa Fe.		
	Mean.	Absolute max.	Max./mean.	Mean.	Absolute max.	Max./mean.	Mean.	Absolute max.	Max./mean.	Mean.	Absolute max.	Max./mean.
	cal.	*cal.*	*ratio.*	*cal.*	*cal.*	*ratio.*	*cal.*	*cal.*	*ratio.*	*cal.*	*cal.*	*ratio.*
Dec. 21	1.18	1.48	1.25	1.30	1.47	1.15	1.32	1.51	1.14	1.49	1.61	1.08
Jan. 21	1.24	1.42	1.15	1.35	1.56	1.16	1.36	1.52	1.12	1.52	1.66	1.09
Feb. 21	1.35	1.50	1.11	1.44	1.57	1.09	1.43	1.58	1.10	1.50	1.65	1.10
Mar. 21	1.34	1.48	1.10	1.51	1.60	1.06	1.42	1.56	1.10	1.54	1.66	1.08
Apr. 21	1.30	1.51	1.16	1.39	1.58	1.14	1.39	1.58	1.14	1.51	1.64	1.09
May 21	1.25	1.45	1.16	1.28	1.47	1.15	1.32	1.53	1.16	1.51	1.61	1.07
June 21	1.25	1.43	1.14	1.28	1.44	1.12	1.33	1.49	1.12	1.42	1.53	1.08
July 21	1.25	1.47	1.18	1.28	1.46	1.14	1.33	1.44	1.08	1.41	1.45	1.03
Aug. 21	1.23	1.43	1.16	1.26	1.46	1.16	1.31	1.49	1.14	1.40	1.47	1.05
Sept. 21	1.26	1.49	1.18	1.22	1.45	1.19	1.35	1.48	1.10	1.47	1.53	1.04
Oct. 21	1.25	1.45	1.16	1.22	1.46	1.20	1.36	1.53	1.12	1.49	1.57	1.05
Nov. 21	1.24	1.48	1.19	1.24	1.42	1.15	1.36	1.56	1.15	1.52	1.63	1.07
Means			1.16			1.14			1.12			1.07

Table 6, giving the monthly means and absolute maxima of noon radiation measurements, indicates that at midday on exceptionally clear days radiation intensities from 15 to 20 per cent greater than the average are to be expected in the eastern States, from 10 to 15 per cent greater in the Plains States, and from 5 to 10 per cent greater on the Rocky Mountain plateau.

INCREASE OF SOLAR RADIATION INTENSITY WITH ALTITUDE.

For a study of the increase in radiation intensity with altitude, in addition to the data contained in Tables 5 and 6, there are available measurements made by the Weather Bureau at Mount Weather, Va.,[12] between September, 1907, and September, 1914, inclusive; by the Smithsonian Institution on Hump Mountain, N. C.,[13] between June, 1917, and March, 1918, inclusive; on Mount Wilson, Calif., in 1908, 1909, 1910, and 1911; and on Mount Whitney, Calif., in 1908, 1909, and 1910;[14] by A. Ångström on Mount Whitney in 1913;[15] and by the writer at Cheyenne, Wyo., and Flagstaff and Phoenix, Ariz.,[16] in 1910, and at Ellijay, N. C., in 1915. These data are summarized in Table 7. They are probably adequate to establish monthly mean values at Mount Wilson, but are insufficient to establish such values at other points. During the time when most of the readings were made at Mount Weather the atmospheric transmission was much below the normal, due to the high dust layer resulting from the eruption of Katmai Volcano in June, 1912. On Mount Whitney readings were obtained on 18 half-day periods; at Flagstaff, 8; at Phoenix, 11; at Cheyenne, 5; and at Ellijay, 5. With the exception of Cheyenne and Mount Weather, these stations are not far from latitude 36° N. We shall therefore consider that they represent intensities at that latitude after applying a correction for the sun's zenith distance where necessary.

TABLE 7.—*Monthly averages of solar radiation intensity.*

(Gram-calories per minute per square centimeter of normal surface.)

Month.	Air mass.		Noon intensities.			
	1.0[1]	2.0	Max.	Min.	Mean.	Max./Mean.
MOUNT WHITNEY, CALIF., LAT. 36° 35′ N.; LONG. 118° 17′ W.; ALT. 14,502 FT. (4,420 M.).						
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Aug. 12–Sept. 3		1.51	1.73	1.60	1.65	1.05
MOUNT WILSON, CALIF., LAT. 34° 13′ N.; LONG. 118° 4′ W.; ALT. 5,767 FT. (1,789 M.).						
May	1.52	1.34	1.57	1.46	1.51	1.04
June	1.52	1.34	1.59	1.41	1.52	1.05
July	1.50	1.34	1.59	1.37	1.49	1.07
August	1.52	1.35	1.65	1.34	1.51	1.09
September		1.40	1.61	1.43	1.53	1.05
October		1.44	1.62	1.40	1.53	1.06
November		1.48	1.58	1.43	1.53	1.03
Mean						1.06
HUMP MOUNTAIN, N. C., LAT. 36° 8′ N.; LONG. 82° 0′ W.; ALT. 4,800 FT. (1,463 M.).						
June		1.29				
July		1.12				
August		1.24				
September		1.36				
October		1.38				
November		1.41				
December		1.46				
January		1.52				
February		1.44				
March		1.46				
MOUNT WEATHER, VA., LAT. 39° 4′ N.; LONG. 77° 53′ W.; ALT. 1,772 FT. (540 M.).						
January		1.34	1.37			
February		1.25	1.48			
March		1.23	1.48			
April		1.17	1.45			
May		0.99	1.50			
June		1.03	1.47			
July		0.99	1.48			
August		1.05	1.45			
September		1.14	1.50			
October		1.32	1.48			
November		1.26	1.43			
December		1.30	1.40			

[12] See Bull. of the Mount Weather Observatory, 5:295–311, and 6:215–219; Monthly Weather Review, 1914, 42:139, 310, 520.

[13] From the manuscript of a table that will appear in Annals of the Astrophysical Observatory, Vol. IV, and kindly furnished by Assistant Secretary Abbot.

[14] Annals of the Astrophysical Observatory of the Smithsonian Institution, 3:74–99.

[15] A study of the radiation of the atmosphere. Smithsonian Misc. Col. 65: No. 3, p. 152, 1915.

[16] Some causes of the variation in the polarization of skylight. Jr. Franklin Instit., April, 1911, p. 338.

Month.	Air mass.		Noon intensities.			
	1.0[1]	2.0	Max.	Min.	Mean.	Max./Mean.
FLAGSTAFF, ARIZ., LAT. 35° 12' N.; LONG. 111° 37' W.; ALT. 6,907 FT. (2,105 M.).						
	cal.	cal.	cal.	cal.	cal.	cal.
Sept. 25-30	1.59	1.40	1.57	....	1.55	....
CHEYENNE, WYO., LAT. 41° 8' N.; LONG. 104° 48' W.; ALT. 6,088 FT. (2,105 M..)						
Aug. 29-Sept. 3	1.47	1.18	1.47	....	1.43	....
ELLIJAY, N. C., LAT. 35° 11' N.; LONG. 83° 15' W.; ALT. 2,240 FT. (683 M.)						
May 8-13	1.43	1.21	....	....	....	....
PHOENIX, ARIZ., LAT. 33° 28' N.; LONG. 112° 0' W.; ALT. 1,108 FT. (336 M.).						
Oct. 2-8	1.47	1.28	1.48	....	1.43	....

[1] Extrapolated.

In curves I-IV, figure 5 is plotted the percentage increase in radiation intensity along the thirty-sixth parallel from the Atlantic Coast States to the Rocky Mountain plateau. Curve I has been derived from the monthly mean intensities with the sun at zenith distance 60°; curve II, from the monthly mean noon intensities of Tables 6 and 7; curve III, from the maximum noon intensities of tables 6 and 7; and curve IV, from the maximum intensities that have been recorded at the respective stations, reduced to zenithal sun and mean solar distance of the earth. Great weight has been given to the data derived from the Washington, Lincoln, and Santa Fe data, as these stations are more representative of general conditions than are mountain stations. The data for the latter for curves I, II, and III, are generally high, indicating that the average radiation intensity on a mountain peak is higher than on a plateau of the same elevation. The intensity at Mount Wilson for curve IV is low, probably because readings have not been made there in winter when the vapor content of the atmosphere is least. A high degree of accuracy can not be claimed for the extreme readings on individual days of curve IV, and especially where they have been extrapolated to air mass 1 from about air mass 2, as has been the case with the readings for Washington, Lincoln, and Santa Fe.

Curves V, VI, VII, and VIII, figure 5, are based upon the increase in the "Daily totals of radiation" of Tables 9b and 9c for latitudes 36° and 42° N., over the corresponding totals of Table 9a. It is to be noted that for the cold season of the year, when the altitude of the sun at noon is low, curves V and VI approximate to curve I; but for the warm season of the year, when the sun is near the zenith at noon, curves VII and VIII approximate to curve II.

The intensities for Phoenix, Ariz., given in Table 7, are only slightly higher than the October intensities for the Plains States at latitude 36°, and the corresponding vapor pressures are also about equal. The few readings obtained at Ellijay, N. C., are higher than one would expect for the elevation of that station.

Curve II is comparable with the results previously obtained by the writer,[17] namely, an increase in radiation intensity of about 5 per cent per 1,000 feet between 720 and 1,720 feet elevation, and of about 0.5 per cent per 1,000 feet between 7,000 and 12,000 feet elevation. Curve IV may be compared with Abbot's[18] determination, which gave less than 1 per cent increase per 1,000 feet between Mount Wilson and Mount Whitney. The radiation intensities upon which curve IV is based, and the dates when observed, are as follows: Washington, D. C., 1.65, Dec. 26, 1914; Lincoln, Nebr., 1.71, Feb. 1, 1917; Santa Fe, N. Mex., 1.75, Feb. 1, 1917; Mount Wilson, Calif., 1.70, Aug. 13, 1909; Mount Whitney, Calif., 1.77, Aug. 17, 1910. These values differ slightly from those employed by Abbot.

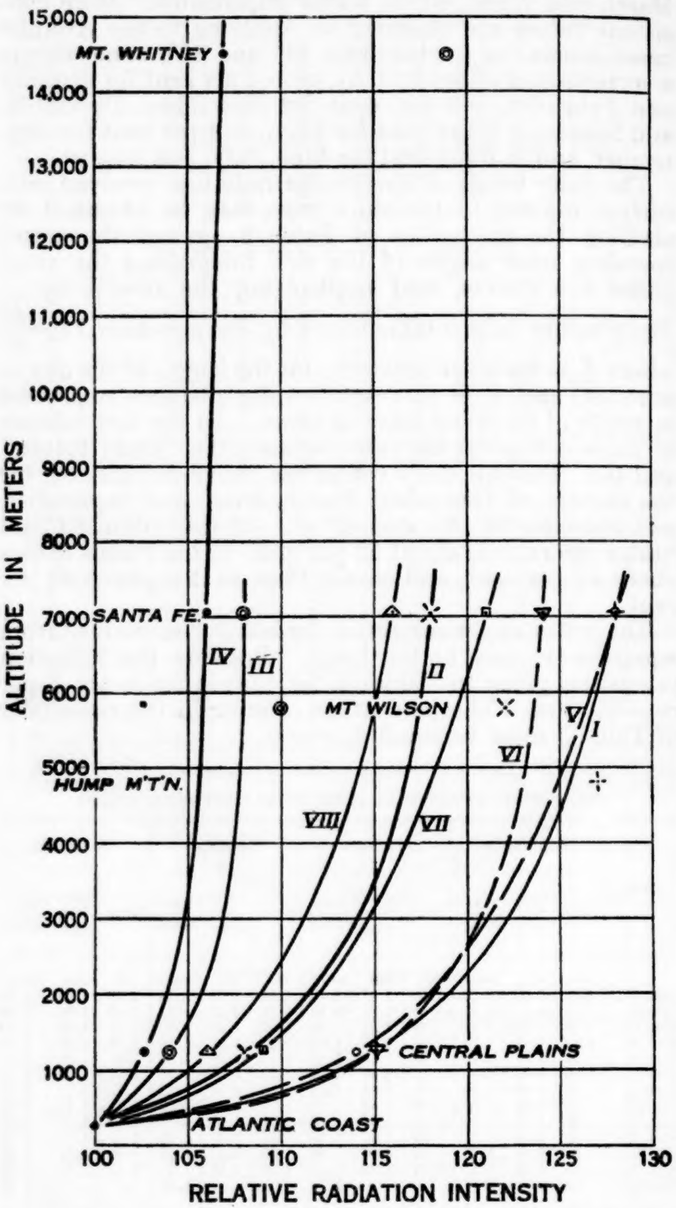


FIGURE 5.—Increase in solar radiation intensity with altitude, westward from the Atlantic Coast. Curve I (⊞), from monthly mean intensities with the sun at zenith distance 60°. Curve II (⊠), from monthly mean noon intensities. Curve III (◎), from maximum noon intensities. Curve IV (●), from absolute maximum intensities, reduced to zenithal sun and mean solar distance of the earth. Curve V (⊙), from daily totals of radiation, Oct. to Jan., incl., at Lat. 36°N. Curve VI (▽), from daily totals of radiation, Oct. to Mar., incl., at Lat. 42°N. Curve VII (⊡), from daily totals of radiation, Feb. to Sept., incl., at Lat. 36°N. Curve VIII (△), from daily totals of radiation, Apr. to Sept., incl., at Lat. 42°N.

[17] Observations on the increase in isolation with elevation. Bull. Mt. Weather Obs. 6: 107-110.

[18] New evidences of the intensity of solar radiation outside the atmosphere. Smithsonian Misc. Col., vol. 65, No. 4, p. 53-54.

The noon radiation intensities measured at Cheyenne average 14 per cent higher than the corresponding intensities for the northeastern part of the United States at latitude 42° N., and 8 per cent higher than the corresponding intensities for the Plains States. This is slightly less increase than is shown at latitude 36°, but is closely in accord with Curve VIII, figure 5. The mean intensities at Mount Weather under normal sky conditions with the sun at zenith distance 60° average only 8 per cent higher than the corresponding Washington intensities. This is less than curve I would lead us to expect. Evidently the curves of figure 5 include the effect of decreased humidity with increase in distance from the ocean, as well as altitude effect.

TOTAL RADIATION ON A HORIZONTAL SURFACE.

The vertical component of the total radiation (direct solar plus diffuse radiation from the sky) at any hour of the day with a clear sky may be computed by the equation

$$Q_H = \frac{Q_m \sin a}{r}$$

in which Q_m is the radiation intensity at normal incidence, for different hour angles of the sun, given in Table 5; a is the corresponding altitude of the sun given in Table 1; and r is the ratio of the vertical component of direct solar radiation to the total (direct plus diffuse) radiation. The ratio r has been obtained from a great number of measurements made at Washington, Madison, and Lincoln,[19] and the results are summarized in Table 8. The ratios for Washington are also shown graphically in figure 12. At Madison but few measurements were made with the zenith distance of the sun in excess of 60°. The ratios for low sun at that station should therefore be given little weight.

TABLE 8.—*Ratio of the vertical component of direct solar radiation to the total radiation received on a horizontal surface.*

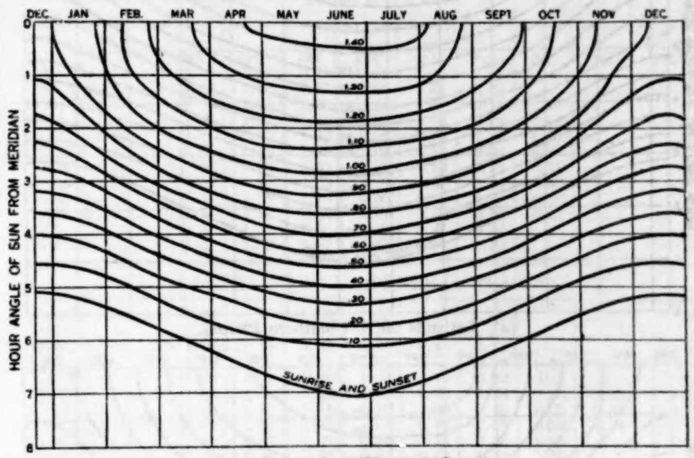
	Sun's zenith distance.									
	30°.0	48°.3	60°.0	66°.5	70°.7	73°.6	75°.7	77°.4	78°.7	79°.8
Ratios for Washington	0.84	0.83	0.815	0.79	0.76	0.73	0.71	0.69	0.68	0.67
Ratios for Lincoln....	0.85	0.84	0.81	0.79	0.76	0.73	0.70	0.67	0.65	0.63
Ratios for Madison...	0.84	0.84	0.76	0.75	0.74	0.66	0.64	......	......	......

On account of the clearer skies at Lincoln we would expect the ratio r to be larger there than at Washington,[20] as it is, until the sun is 60° distant from the zenith. That the reverse is true with low sun may be due to inaccuracies in the records from the Callendar pyrheliometers. However, the ratios determined at Washington have been used in computing the total radiation on a horizontal surface for the Eastern States, and those determined at Lincoln in computations for the Plains States and the Plateau, and the results are given in Tables 9a, 9b, and 9c, and figures 6, 7, and 8. It is to be noted that a considerable error in the value of r, for zenith distances of the sun greater than 60°, will introduce comparatively small errors in the computed total radiation received on a horizontal surface during a half-day period.

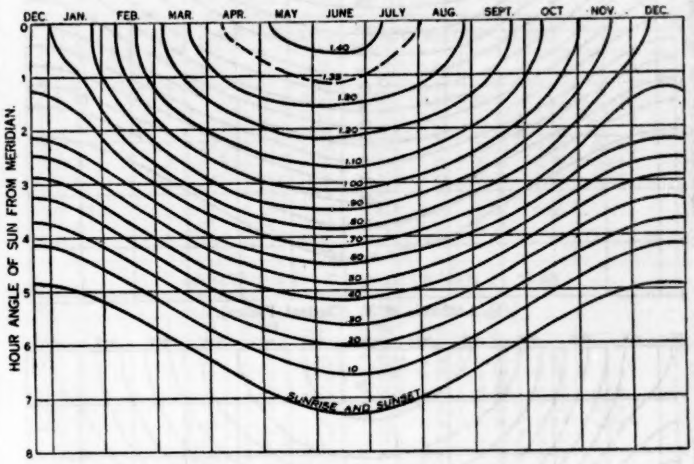
[19] For a description of the manner in which these measurements were obtained, see the MONTHLY WEATHER REVIEW, August, 1914, 42: 477–479. See also "A new instrument for measuring sky radiation," by Anders Ångström, This Review, pp. 795–797.

[20] See also "Some problems relating to the scattered radiation from the sky," by Anders Ångström. This Review, pp. 797–798.

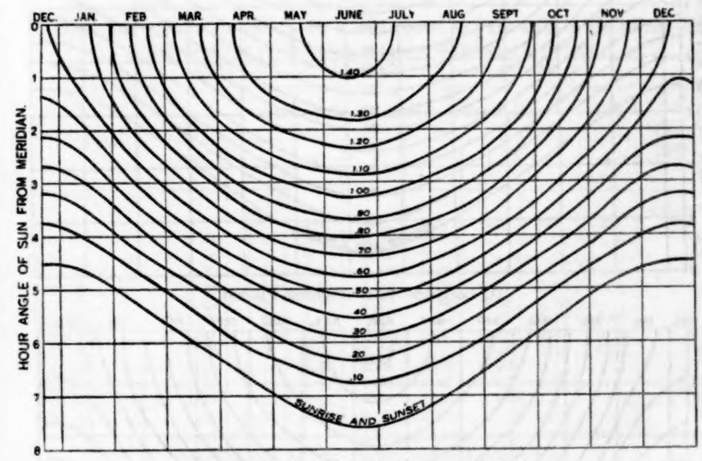
This latter is obtained by plotting the radiation intensities of Table 9 against the hour angle of the sun, and graphically integrating the area under the curve. Multiplied by 2 the results give the daily totals of the above tables.



(a), Latitude 30°N. (Gulf Coast).



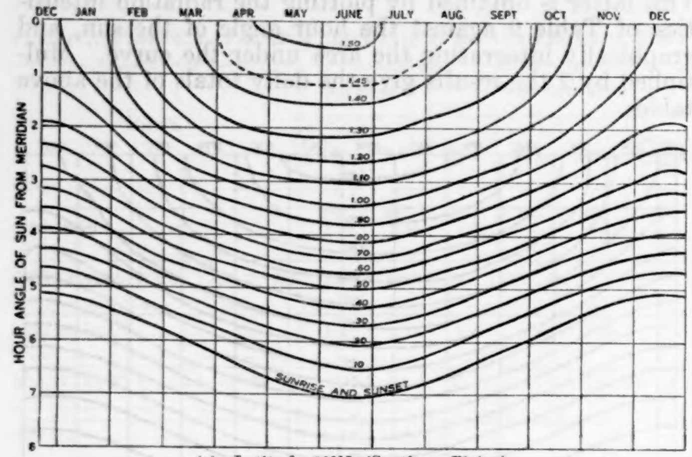
(b), Latitude 36°N. (Eastern States).



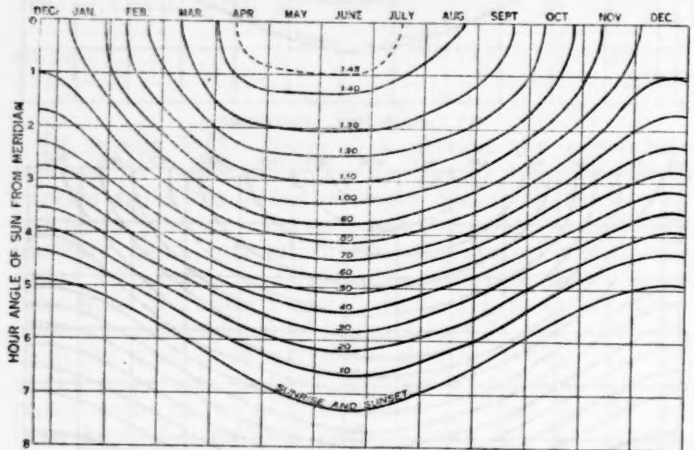
(c), Latitude 42°N. (Northeastern States).

FIGURE 6.—Total radiation intensity on a horizontal surface with a cloudless sky. (Gram calories per minute per square centimeter.)

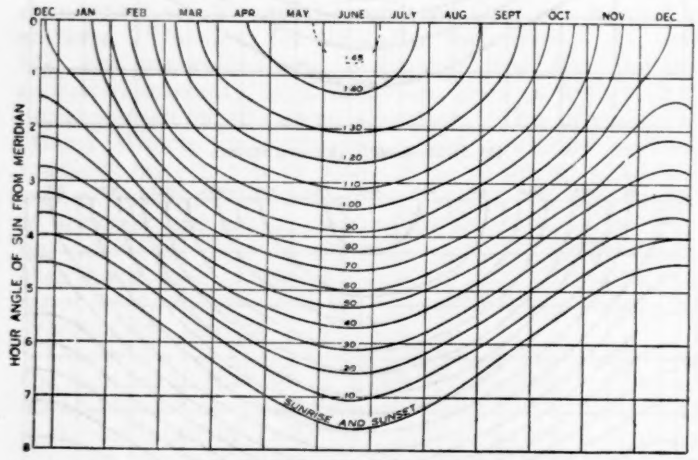
It is worthy of note that in Tables 9a and 9b the ratio of the daily total of radiation on June 21 to the daily total on Dec. 21, for latitude 30° N., is 2.09; while with an atmospheric transmission coefficient of 1.0, and



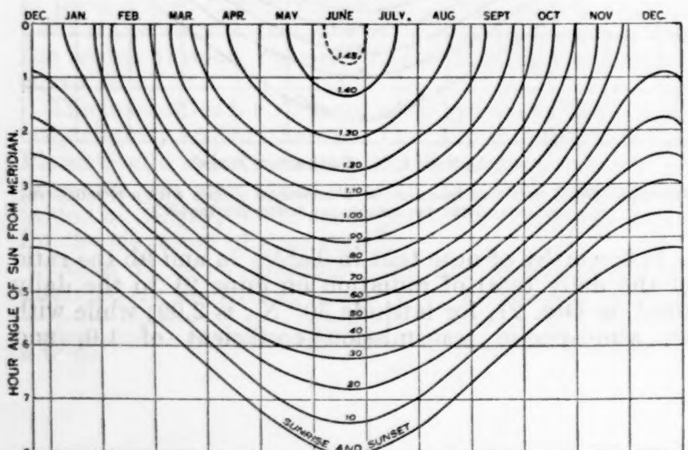
(*a*), Latitude 30°N. (Southern Plains).



(*b*), Latitude 36°N. (Central Plains).

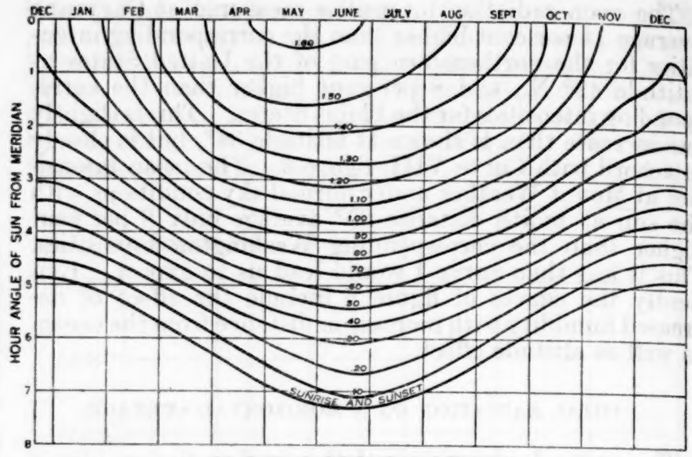


(*c*), Latitude 42°N (Central Plains).

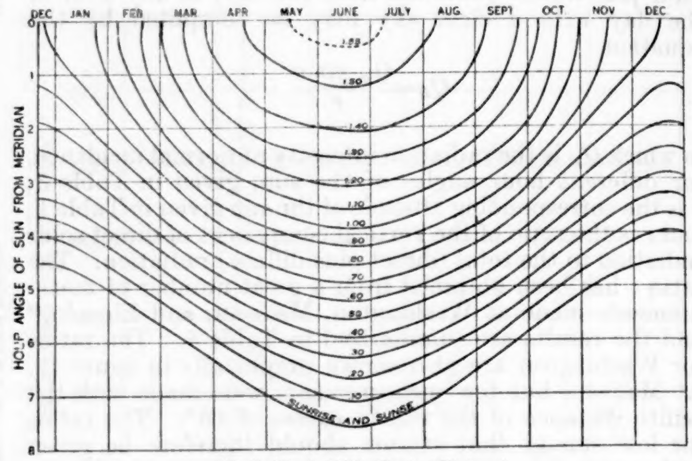


(*d*), Latitude 48°N. (Northern Plains.)

FIGURE 7.—Total radiation intensity on a horizontal surface with a cloudless sky. (Gram calories per minute per square centimeter.)



(*a*), Latitude 36°N. (Central Plateau).



(*b*), Latitude 42°N. (Central Plateau).

FIGURE 8.—Total radiation intensity on a horizontal surface with a cloudless sky. (Gram calories per minute per square centimeter.)

neglecting the diffuse radiation from the sky, Angot's [21] computations give 2.09 for the ratio of the maximum to the minimum heat received in a day at latitude 30° N., and 2.07 for the ratio of the total heat received in June to that received in December. At latitude 48° N., Table 9b gives for the daily totals on June 21 and December 21 the ratio 5.1, while Angot's computations as above give 4.8 for the ratio of the maximum to the minimum daily amounts and 4.7 for the ratio of the June to the December monthly totals. The ratios for Angot's computations increase rapidly with decreasing atmospheric transmission. Indeed, assuming the transmission in December to be 0.8 and in June 0.7, at latitude 30° N. the ratio for the maximum to the minimum daily radiation, and also for the June to the December monthly radiation, becomes 2.1, while at latitude 48° the corresponding ratios become 7.5 and 6.5, respectively. The fact that under these circumstances Angot's computations show a less relative radiation intensity in winter than in summer, and less at high latitudes than at low latitudes, than is shown by Table 9, is to be attributed to the increase in the ratio of diffuse radiation to direct solar radiation with decrease in the sun's altitude, as shown by Table 8. This is also shown by the computations of Schmidt [22].

[21] Angot, Alfred. Recherches théoretiques sur la distribution de la chaleur a la surface du globe. Annales du Bureau Central Météorologique de France, Année 1883, B121-169.

[22] Schmidt, Wilhelm. Strahlung und Verdunstung an freien Wasserflächen usw. Annalen der Hydrographie und Maritimen Meteorologie, März. 1915, S 121.

By drawing a smooth curve through the plotted daily totals of radiation for the different latitudes in the Eastern and in the Plains States the daily totals for the latitudes of Washington and of Lincoln, respectively, have been obtained, and are given in Table 10, in the column headed "Computed." The computed daily totals for Madison were obtained directly from the vertical component of the monthly means of direct solar radiation and the ratios of Table 8. These computed daily totals may be compared with the daily maxima and the daily normals of total radiation, given in Table 10. The daily normals have been obtained from the data published in the REVIEW in "Solar and Sky Radiation Measurements," Table 3, July, 1918, to June, 1919, inclusive. The observed daily maxima for Madison are somewhat low as compared with the computed daily totals, partly, no doubt, because in reducing the Callendar records at that station the selective absorption of the bright (platinum) grids has not been taken into account, as it has been at Washington,[23] and Lincoln,[24] and also in the computed daily totals. In order that they may be comparable with the remaining data of the table the Madison observed daily maxima and daily normals should be increased by about 2 per cent and 1 per cent, respectively. The selective absorption of the bright grids has been taken into account in computing the ratios of Table 8 for Madison.

TABLE 9a.—*Total radiation on a horizontal surface with a cloudless sky.*

(Gram calories per minute per square centimeter of surface.

LATITUDE 30° N. (GULF COAST.)

Date.	Hour angle of sun from the meridian.								Daily Total.
	0	1	2	3	4	5	6	7	
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal. per cm².*
Dec. 21	0.87	0.81	0.66	0.44	0.20	0.01	......	......	307
Jan. 21	0.96	0.92	0.77	0.51	0.24	0.03	......	......	352
Feb. 21	1.18	1.13	0.96	0.70	0.38	0.12	......	......	465
Mar. 21	1.30	1.24	1.07	0.83	0.49	0.20	0.01	......	539
Apr. 21	1.35	1.31	1.15	0.93	0.63	0.30	0.07	......	605
May 21	1.37	1.32	1.17	0.94	0.66	0.36	0.10	......	625
June 21	1.37	1.32	1.18	0.97	0.70	0.39	0.13	......	643
July 21	1.39	1.35	1.19	0.98	0.68	0.38	0.12	......	644
Aug. 21	1.31	1.26	1.11	0.88	0.58	0.29	0.07	......	579
Sept. 21	1.24	1.18	1.03	0.79	0.49	0.18	0.01	......	516
Oct. 21	1.08	1.04	0.89	0.63	0.35	0.10	......	......	425
Nov. 21	0.96	0.89	0.74	0.51	0.24	0.03	......	......	345

LATITUDE 36° N. (EASTERN U. S.)

Date.	0	1	2	3	4	5	6	7	Daily Total.
Dec. 21	0.77	0.71	0.67	0.36	0.13	......	......	......	260
Jan. 21	0.86	0.80	0.66	0.43	0.20	......	......	......	307
Feb. 21	1.10	1.07	0.90	0.65	0.35	0.07	......	......	431
Mar. 21	1.30	1.22	1.08	0.82	0.51	0.21	0.01	......	540
Apr. 21	1.39	1.35	1.18	0.97	0.66	0.35	0.10	......	637
May 21	1.40	1.36	1.20	1.00	0.72	0.43	0.18	0.01	672
June 21	1.43	1.38	1.24	1.04	0.75	0.46	0.20	0.02	694
July 21	1.43	1.37	1.23	1.01	0.73	0.44	0.19	0.01	683
Aug. 21	1.32	1.26	1.12	0.89	0.61	0.33	0.10	......	596
Sept. 21	1.22	1.18	1.03	0.79	0.49	0.20	0.01	......	517
Oct. 21	1.04	1.00	0.83	0.60	0.32	0.07	......	......	401
Nov. 21	0.87	0.82	0.66	0.43	0.19	......	......	......	309

LATITUDE 42° N. (NORTHEASTERN U. S.)

Date.	0	1	2	3	4	5	6	7	Daily Total.
Dec. 21	0.59	0.54	0.43	0.24	0.05	......	......	......	212
Jan. 21	0.71	0.66	0.52	0.33	0.12	......	......	......	239
Feb. 21	1.00	0.95	0.79	0.56	0.31	0.05	......	......	379
Mar. 21	1.20	1.15	1.00	0.76	0.48	0.20	0.01	......	505
Apr. 21	1.36	1.32	1.17	0.96	0.68	0.38	0.13	......	640
May 21	1.43	1.38	1.24	1.02	0.78	0.49	0.24	0.02	709
June 21	1.45	1.40	1.28	1.07	0.81	0.54	0.27	0.06	744
July 21	1.43	1.38	1.24	1.04	0.79	0.49	0.26	0.02	715
Aug. 21	1.30	1.26	1.12	0.91	0.66	0.35	0.11	......	610
Sept. 21	1.17	1.11	0.98	0.75	0.47	0.20	0.01	......	494
Oct. 21	0.93	0.88	0.74	0.52	0.28	0.05	......	......	352
Nov. 21	0.71	0.67	0.53	0.33	0.12	......	......	......	241

[23] See the MONTHLY WEATHER REVIEW for August, 1914, 42: 476-80. Jan. 1916, 44: 4.
[24] See the MONTHLY WEATHER REVIEW for April, 1916, 44: 179.

TABLE 9b.—*Total radiation on a horizontal surface with a cloudless sky.*

(Gram-calories per minute per square centimeter of surface.)

LATITUDE 30° N. (SOUTHERN PLAINS.)

Date.	Hour angle of sun from the meridian.								Daily Total.
	0	1	2	3	4	5	6	7	
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal. per cm².*
Dec. 21	0.97	0.93	0.78	0.54	0.28	0.01	......	......	363
Jan. 21	1.07	1.02	0.87	0.64	0.33	0.04	......	......	410
Feb. 21	1.28	1.23	1.06	0.81	0.50	0.16	......	......	527
Mar. 21	1.42	1.37	1.20	0.96	0.63	0.28	0.01	......	619
Apr. 21	1.50	1.45	1.30	1.05	0.74	0.39	0.10	......	690
May 21	1.49	1.45	1.29	1.07	0.81	0.45	0.16	......	718
June 21	1.52	1.48	1.34	1.11	0.84	0.51	0.21	......	759
July 21	1.52	1.47	1.32	1.10	0.81	0.46	0.17	......	731
Aug. 21	1.43	1.38	1.24	1.00	0.70	0.37	0.10	......	657
Sept. 21	1.36	1.31	1.15	0.91	0.59	0.25	0.01	......	588
Oct. 21	1.22	1.17	1.01	0.78	0.46	0.14	......	......	500
Nov. 21	1.07	1.02	0.87	0.63	0.33	0.04	......	......	408

LATITUDE 36° N. (CENTRAL PLAINS.)

Date.	0	1	2	3	4	5	6	7	Daily Total.
Dec. 21	0.85	0.80	0.66	0.45	0.17	......	......	......	300
Jan. 21	0.94	0.90	0.76	0.53	0.25	......	......	......	353
Feb. 21	1.19	1.14	0.97	0.75	0.45	0.13	......	......	483
Mar. 21	1.35	1.29	1.15	0.91	0.61	0.28	0.01	......	591
Apr. 21	1.49	1.43	1.29	1.07	0.77	0.42	0.13	......	702
May 21	1.48	1.44	1.29	1.07	0.80	0.48	0.24	0.02	730
June 21	1.48	1.45	1.31	1.10	0.85	0.53	0.25	0.03	748
July 21	1.49	1.45	1.31	1.08	0.81	0.49	0.26	0.02	741
Aug. 21	1.41	1.35	1.22	0.99	0.72	0.38	0.13	......	638
Sept. 21	1.30	1.25	1.10	0.86	0.56	0.23	0.01	......	559
Oct. 21	1.13	1.08	0.93	0.70	0.41	0.10	......	......	452
Nov. 21	0.94	0.90	0.75	0.53	0.25	......	......	......	352

LATITUDE 42° N. (CENTRAL PLAINS.)

Date.	0	1	2	3	4	5	6	7	Daily Total.
Dec. 21	0.69	0.65	0.53	0.34	0.10	......	......	......	236
Jan. 21	0.81	0.75	0.63	0.43	0.17	......	......	......	286
Feb. 21	1 07	1.02	0.88	0.65	0.37	0.08	......	......	423
Mar. 21	1.31	1.25	1.12	0.89	0.61	0.29	0.01	......	580
Apr. 21	1.41	1.37	1.23	1.02	0.77	0.45	0.18	......	688
May 21	1.46	1.41	1.28	1.08	0.83	0.52	0.25	0.03	736
June 21	1.48	1.44	1.32	1.13	0.87	0.59	0.32	0.10	786
July 21	1.46	1.41	1.28	1.10	0.83	0.53	0.25	0.04	740
Aug. 21	1.34	1.30	1.17	0.96	0.71	0.41	0.15	......	646
Sept. 21	1.22	1.17	1.03	0.81	0.53	0.24	0.01	......	529
Oct. 21	1.01	0.96	0.84	0.62	0.34	0.08	......	......	400
Nov. 21	0.80	0.75	0.63	0.42	0.17	......	......	......	284

LATITUDE 48° N. (NORTHERN PLAINS.)

Date.	0	1	2	3	4	5	6	7	Daily Total.
Dec. 21	0.52	0.49	0.37	0.19	0.02	......	......	......	160
Jan. 21	0.65	0.60	0.47	0.30	0.08	......	......	......	212
Feb. 21	0.92	0.87	0.75	0.57	0.30	0.04	......	......	359
Mar. 21	1.20	1.14	1.01	0.81	0.55	0.25	0.01	......	527
Apr. 21	1.34	1.29	1.18	0.99	0.75	0.47	0.22	......	670
May 21	1.41	1.38	1.26	1.08	0.84	0.58	0.31	0.08	749
June 21	1.48	1.44	1.33	1.15	0.92	0.65	0.35	0.16	809
July 21	1.44	1.41	1.29	1.10	0.86	0.58	0.32	0.08	762
Aug. 21	1.31	1.27	1.15	0.97	0.71	0.44	0.20	......	649
Sept. 21	1.13	1.08	0.96	0.75	0.50	0.22	0.01	......	493
Oct. 21	0.88	0.83	0.71	0.53	0.29	0.03	......	......	340
Nov. 21	0.63	0.59	0.48	0.29	0.08	......	......	......	210

TABLE 9c.—*Total radiation on a horizontal surface with a cloudless sky.*

(Gram-calories per minute per square centimeter of surface.)

LATITUDE 36° N. (CENTRAL PLATEAU.)

Date.	Hour angle of sun from the meridian.								Daily Total.
	0	1	2	3	4	5	6	7	
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal. per cm².*
Dec.21	0.94	0.88	0.75	0.52	0.23	......	......	......	340
Jan. 21	1.04	1.00	0.84	0.61	0.30	......	......	......	397
Feb. 21	1.25	1.19	1.05	0.80	0.49	0.15	......	......	516
Mar. 21	1.48	1.42	1.27	1.02	0.70	0.34	0.01	......	666
Apr. 21	1.60	1.56	1.39	1.15	0.84	0.50	0.15	......	766
May 21	1.71	1.65	1.49	1.26	0.94	0.62	0.32	0.02	858
June 21	1.61	1.56	1.43	1.24	0.95	0.63	0.32	0.14	843
July 21	1.60	1.55	1.41	1.18	0.89	0.58	0.26	0.02	800
Aug. 21	1.50	1.44	1.31	1.08	0.79	0.46	0.15	......	717
Sept. 21	1.42	1.36	1.21	0.96	0.65	0.32	0.01	......	626
Oct. 21	1.22	1.18	1.01	0.77	0.46	0.13	......	......	498
Nov. 21	1.04	0.98	0.84	0.61	0.30	......	......	......	393

LATITUDE 42° N. (CENTRAL PLATEAU.)

Date.	0	1	2	3	4	5	6	7	Daily Total.
Dec. 21	0.79	0.72	0.58	0.37	0.10	......	......	......	261
Jan. 21	0.87	0.83	0.70	0.47	0.20	......	......	......	315
Feb. 21	1.10	1.06	0.91	0.69	0.41	0.08	......	......	443
Mar. 21	1.35	1.31	1.16	0.94	0.66	0.32	0.01	......	610
Apr. 21	1.52	1.46	1.32	1.11	0.82	0.50	0.20	......	739
May 21	1.64	1.59	1.44	1.24	0.94	0.65	0.35	0.04	848
June 21	1.58	1.52	1.41	1.22	0.97	0.67	0.37	0.13	854
July 21	1.54	1.49	1.36	1.15	0.89	0.61	0.31	0.04	769
Aug. 21	1.48	1.43	1.30	1.08	0.80	0.50	0.19	......	727
Sept. 21	1.34	1.28	1.13	0.91	0.63	0.33	0.01	......	596
Oct. 21	1.08	1.02	0.89	0.67	0.40	0.08	......	......	431
Nov. 21	0.87	0.83	0.70	0.47	0.19	......	......	......	314

TABLE 10.—*Daily totals of solar and sky radiation on a horizontal surface.*

[Gram-calories per square centimeter.]

WASHINGTON, D. C.

Dates.	Computed.	Observed.		Ratio.	Monthly means.	
		Maximum.	Normal.	Normal. / Computed.	Cloudiness 0-10.	Percentage of possible sunshine.
	cal.	*cal.*	*cal.*			
Dec. 21	237	297	157	0.662	6.5	47.3
Jan. 21	275	346	183	0.665	6.2	50.8
Feb. 21	408	464	269	0.659	5.4	56.7
Mar. 21	528	642	349	0.661	5.0	65.3
Apr. 21	641	714	429	0.669	5.4	58.9
May 21	690	734	494	0.716	5.7	60.3
June 21	718	748	524	0.730	5.3	65.4
July 21	699	667	494	0.707	5.7	59.9
Aug. 21	603	660	431	0.715	4.9	67.5
Sept. 21	508	556	370	0.728	4.6	68.5
Oct. 21	380	454	281	0.740	4.5	62.6
Nov. 21	283	354	198	0.700	4.6	65.5
Means				0.696	5.3	60.8

MADISON, WIS.

Dates.	Computed.	Maximum.	Normal.	Normal. / Computed.	Cloudiness 0-10.	Percentage of possible sunshine.
Dec. 21	227	223	130	0.573	6.5	39.2
Jan. 21	270	306	183	0.678	6.5	45.6
Feb. 21	418	424	263	0.629	6.1	53.5
Mar. 21	573	572	356	0.621	6.4	57.1
Apr. 21	673	713	423	0.629	6.5	54.0
May 21	720	758	470	0.653	6.5	57.9
June 21	766	770	535	0.698	6.0	62.9
July 21	710	788	509	0.717	5.3	69.6
Aug. 21	591	648	425	0.719	5.4	61.6
Sept. 21	491	524	322	0.656	5.6	55.8
Oct. 21	343	358	223	0.650	5.9	48.9
Nov. 21	255	258	143	0.561	6.4	41.0
Means				0.649	6.1	52.0

LINCOLN, NEBR.

Dates.	Computed.	Maximum.	Normal.	Normal. / Computed.	Cloudiness 0-10.	Percentage of possible sunshine.
Dec. 21	250	269	173	0.692	5.8	47.0
Jan. 21	299	328	232	0.776	5.1	65.0
Feb. 21	435	473	316	0.726	5.3	63.0
Mar. 21	582	602	412	0.708	5.2	64.0
Apr. 21	691	724	423	0.612	6.7	47.0
May 21	734	738	517	0.704	5.7	59.0
June 21	780	804	595	0.763	4.1	70.0
July 21	740	765	558	0.754	4.0	75.0
Aug. 21	647	650	472	0.730	4.5	66.0
Sept. 21	535	574	397	0.742	4.6	60.0
Oct. 21	411	428	294	0.715	4.7	58.0
Nov. 21	298	328	209	0.701	4.6	60.0
Means				0.719	5.1	60.0

TABLE 11.—*Relation between cloudiness and radiation—Percentage of clear sky radiation.*

OCTOBER TO MARCH.

Station.	Cloudiness.										
	0	1	2	3	4	5	6	7	8	9	10
Washington	100	99.0	94.3	88.5	83.3	78.5	70.9	66.0	55.3	47.3	23.2
Madison	100	100.2	98.7	94.3	91.0	85.4	82.9	74.8	66.4	59.9	33.0
Lincoln	100	100.5	97.5	92.3	87.4	82.4	78.9	70.7	61.4	53.2	29.6
Mean	100	99.9	96.8	91.7	87.2	82.1	77.6	70.5	61.0	53.5	28.9

APRIL TO SEPTEMBER.

Station.	0	1	2	3	4	5	6	7	8	9	10
Washington	100	99.5	96.0	89.5	84.6	80.0	73.8	66.7	56.9	47.2	26.7
Madison	100	97.1	96.9	91.6	89.4	83.6	78.6	72.4	61.3	53.6	33.7
Lincoln	100	99.0	95.9	91.5	86.8	79.1	75.2	64.9	58.3	45.1	27.8
Mean	100	98.5	96.3	90.9	86.9	80.9	75.9	68.0	58.8	48.6	29.4

YEAR.

Station.	0	1	2	3	4	5	6	7	8	9	10
Washington	100	99	95	89	84	79	72	66	56	47	25
Madison	100	99	98	93	90	84	81	74	64	57	33
Lincoln	100	100	97	92	87	81	77	68	60	50	29
Mean	100	99	97	91	87	81	77	69	60	51	29

TABLE 12.—*Relation between percentage of possible sunshine and radiation—Percentage of clear sky radiation.*

OCTOBER TO MARCH.

Station.	Percentage of possible sunshine.											
	100	94.5	84.5	74.5	64.5	54.5	44.5	34.5	24.5	14.5	5.0	0
Washington	100	94.5	90.5	85.5	76.0	68.5	60.0	59.0	53.5	43.0	33.0	21.0
Madison	100	97.0	93.0	89.0	83.0	77.0	75.0	59.0	61.0	55.0	44.0	26.0
Lincoln	100	97.0	96.0	89.0	83.0	75.5	73.5	68.0	60.0	51.0	40.0	24.0
Mean	100	96.0	93.0	88.0	81.0	74.0	70.0	62.0	58.0	50.0	39.0	24.0

APRIL TO SEPTEMBER.

Station.	100	94.5	84.5	74.5	64.5	54.5	44.5	34.5	24.5	14.5	5.0	0
Washington	100	96	90	95	76	68.5	65	60	46	40	31	19
Madison	100	97	93	86.5	78	70	63	57	49	39.5	31	21
Lincoln	100	96	92	86	79	72	65	59	52	42	29	20
Mean	100	96	92	86	78	70	64	57	49	40	30	20

YEAR.

Station.	100	94.5	84.5	74.5	64.5	54.5	44.5	34.5	24.5	14.5	5.0	0
Washington	100	95	90	85	76	68.5	62	59	50	41.5	32	20
Madison	100	97	93	88	80	74	69	58	55	47	38	23
Lincoln	100	96	94	87	81	74	69	63	56	46	35	22
Mean	100	96	92	87	79	72	67	60	54	45	35	22

RELATION BETWEEN CLOUDINESS, DURATION OF SUNSHINE, AND RADIATION INTENSITY.

From the Callendar records the average daily amount of radiation for each decade, except that for June and December the averages are for the entire month, has been determined for days on which the cloudiness was recorded as 0, 1, 2, 3, etc., to 10, respectively, and also on days for which the percentage of possible sunshine as recorded by the Marvin sunshine recorder was 100, 99–90, 89–80, etc., to 9–1, and 0, respectively. From these decade and monthly averages the seasonal and annual averages of Tables 11 and 12, which are expressed as a "Percentage of clear-sky radiation," have been derived. The seasonal differences are not important. The annual

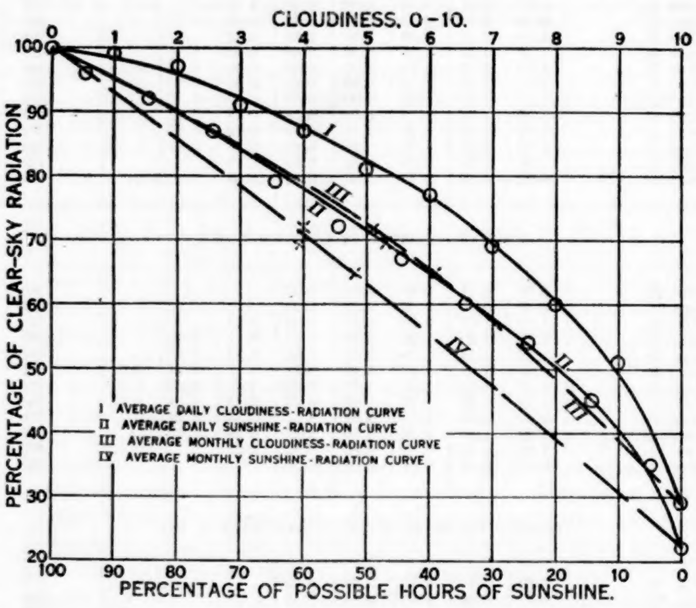


FIGURE 9.—Relation between radiation intensity and average daily and monthly cloudiness and percentage of possible sunshine, expressed as a percentage of the average intensity with a cloudless sky.

averages are shown graphically in figure 9. From this latter it is seen that with the daily cloudiness recorded 10 the radiation averages about 29 per cent of clear-sky radiation. This is a little greater than for zero percent-

age of possible sunshine, namely, 22 per cent, for the reason that the sun may sometimes shine with the sky more than 95 per cent covered with clouds. Also, 50 per cent clear-sky radiation intensity corresponds to an average cloudiness of 9, and to a percentage of possible sunshine of 20; and 50 per cent possible sunshine corresponds to 71 per cent, and 5 cloudiness to 82 per cent, of clear-sky radiation intensity. In general, the percentage of possible hours of sunshine is greater than the cloudiness would lead us to expect, the maximum difference occurring when the sky is rather more than half covered with clouds. This is no doubt partly due (1) to the fact that much recorded cloudiness is of thin clouds and (2) to the fact that the record of cloudiness is based upon the proportion of the sky that *appears* to be covered with clouds. When detached cumulus clouds or broken cloud sheets, especially of strato-cumulus, are viewed nearly edgewise near the horizon, they *appear* to cover a greater percentage of the sky than they really do; and while with the sun near the horizon, when the direct radiation is only about half the total, the sun may be shaded a considerable portion of the time, with the sun near the zenith, when direct solar radiation is more than 0.8 of the total, the sun will be but little shaded.

If we plot on figure 9 the radiation ratios $\frac{\text{normal}}{\text{computed}}$ of Table 10 as ordinates against the monthly or annual cloudiness or the precentage of possible sunshine of the same table as abscissas, it will be seen that they fall at points considerably below the corresponding radiation-cloudiness and radiation-sunshine curves, as we would expect. In fact, the radiation-ratio and sunshine data plot very nearly on the straight line connecting 100-per-cent-sunshine and 0-per-cent-sunshine radiation intensities. We may therefore use the broken-line curves through the points named to determine the percentage relation between clear-sky and actual radiation at points having a greater or less average monthly cloudiness or percentage of possible sunshine than Washington, Madison, or Lincoln.

AVERAGE DAILY TOTALS OF RADIATION.

Figure 10 has been constructed by plotting along the parallels 30° N., 36° N., 42° N., and 48° N., the daily totals of radiation given in table 9, reduced by factors derived from curves V–VIII, figure 5, to the intensities at the 1,000, 2,000, 3,000, and 5,000 foot levels, where necessary. During the cold part of the year the radiation increases rapidly from high to low latitudes, with a maximum increase of over 100 per cent from latitude 48° N. to latitude 30° N. in the Plains States. During the warm part of the year the increase is from the Atlantic coast westward to the Rocky Mountain plateau, with a maximum of 28 per cent at latitude 36° N. in May.

Figure 11, has been constructed by multiplying the plotted daily totals of figure 10 by the percentage of clear-sky radiation, as given by curve IV, figure 9, corresponding to the monthly average percentages of possible hours of sunshine at points where the parallels of 30° N., 36° N., 42., and 48° N. cross the sea level, and the 1,000, 2,000, 3,000, 5,000, and 7,000 foot contour lines. The monthly average percentages of possible hours of sunshine have been obtained from unpublished charts made up by the Climatological Division, Weather Bureau, in connection with the preparation of seasonal charts for the Atlas of American Agriculture. They are based on records by the Marvin sunshine recorder for the years 1905 to 1912, inclusive. In figure 11 the radiation increase from high to low latitude in winter, and from low to high altitude in summer, is even more marked than in figure 10. The increase from the Lakes at Lat. 42° N. to the Gulf at latitude 30° N. is 100 per cent in December and January; and in December, from latitude 48° N. to latitude 30° N. in the Plains States the increase is nearly 200 per cent. In June the increase at latitude 36° N. from the Atlantic coast to the Rocky Mountain plateau s 50 per cent.

THE EFFECT OF SLOPE UPON THE QUANTITY OF SOLAR RADIATION RECEIVED PER UNIT OF SURFACE.

Let ϕ= the latitude of the place, and c the angle of slope. For a south slope the angle of incidence of the solar rays with the surface for different hour angles of the sun will be the same as on a horizontal surface at latitude $\phi-c$. The possible hours of sunshine with *south* or *minus* solar declination will not be changed; but for *north* or *plus* solar declination they will be the same as for latitude $\phi-c$. For a north slope the angle of incidence of the solar rays with the surface for different hour angles of the sun will be the same as at latitude $\phi+c$. The possible hours of sunshine with *north* or *plus* solar declination will not be changed; but for *south* or *minus* declination they will be the same as for latitude $\phi+c$.

Thus, on a south slope of 7 per cent, or 4°, at latitude 35°, the angle of incidence of the solar rays will be the same as on a horizontal surface at 31° N.; and on a south slope of 35°, or 70 per cent, at latitude 35°, the angle of incidence of the solar rays will be the same as on a horizontal surface at the Equator, and from March 21 to September 21, inclusive, the hours of possible sunshine per day will likewise be the same, namely, 12 hours. On a north slope of 45°, or 100 per cent, at latitude 45° N., the angle of incidence of the solar rays will be the same as on a horizontal surface at the north pole. It will receive sunshine only between March 21 and September 21, and the possible hours of sunshine will be the same as at latitude 45°. Such a surface will therefore receive less solar radiation than a horizontal surface at the north pole.

In the case of a slope facing α' degrees in azimuth the angle of incidence of the solar rays will be the same as on a horizontal surface at a point on a great circle passing through the slope at right angles to it and as many degrees removed as the angle of the slope. We may locate this point in latitude and longitude by the solution of the right-angled spherical triangle of which c, the angle of slope, is the hypotenuse, α' is one of the angles, the side b is the difference in longitude between the point and the slope, and side a is the difference in latitude. The computation equations are $\tan b=\frac{\cos\alpha'}{\cot c}$, and $\sin a=\sin\alpha'\sin c$.

Example: At Wagon Wheel Gap, Colo., at latitude 37° 46′ N., longitude 106° 53′ W., and elevation about 10,000 feet, are four slopes, A–2, B–2, A–1, and B–1, facing south 56° east, south 45° east, north 24° west, and north 24° east, and with angular slopes of 34° 20′, 30°, 31° 20′, and 37° 30′, respectively. The points where horizontal surfaces are parallel to those slopes are as follows:

A–2, latitude 16° 52′ north, longitude 79° west.
B–2, latitude 15° 34′ north, longitude 86° 11′ west.
A–1, latitude 66° 51′ north, longitude 119° 6′ west.
B–1, latitude 72° 48′ north, longitude 92° 33′ west.

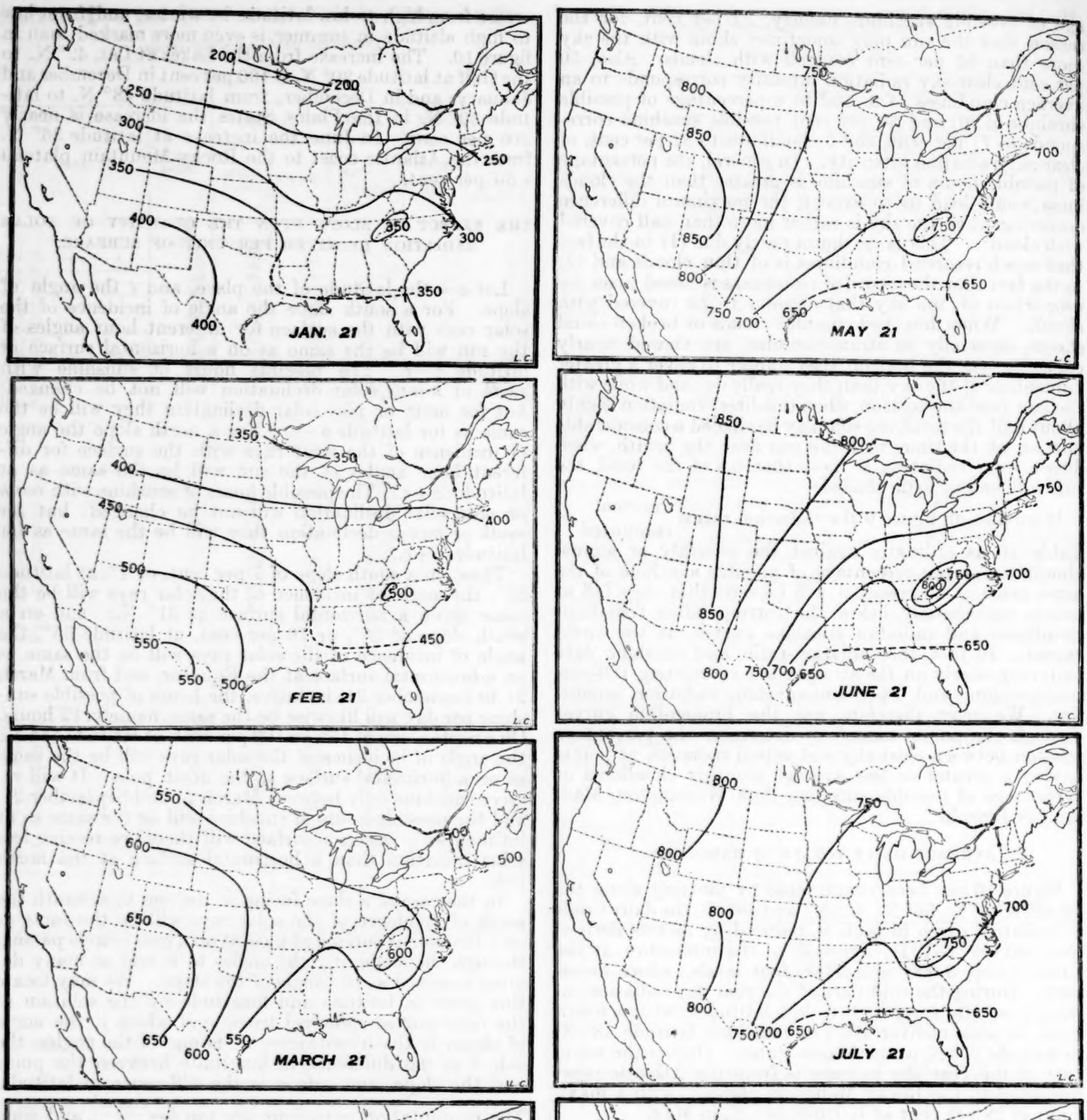


FIGURE 10.—Average daily totals of radiation received on a horizontal surface with a cloudless sky. (Gram calories per minute per square centimeter.)

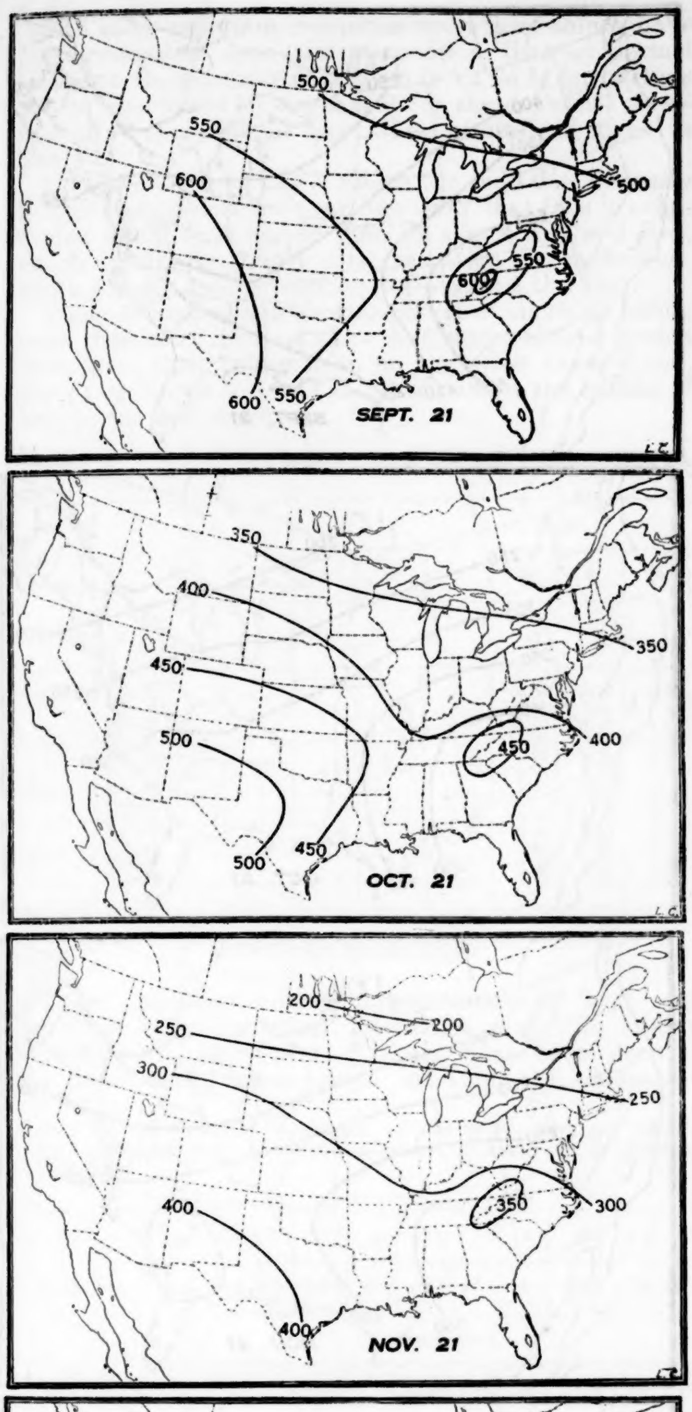


FIGURE 10.—Average daily totals of radiation received on a horizontal surface with a cloudless sky—**Continued**. (Gram calories per minute per square centimeter.)

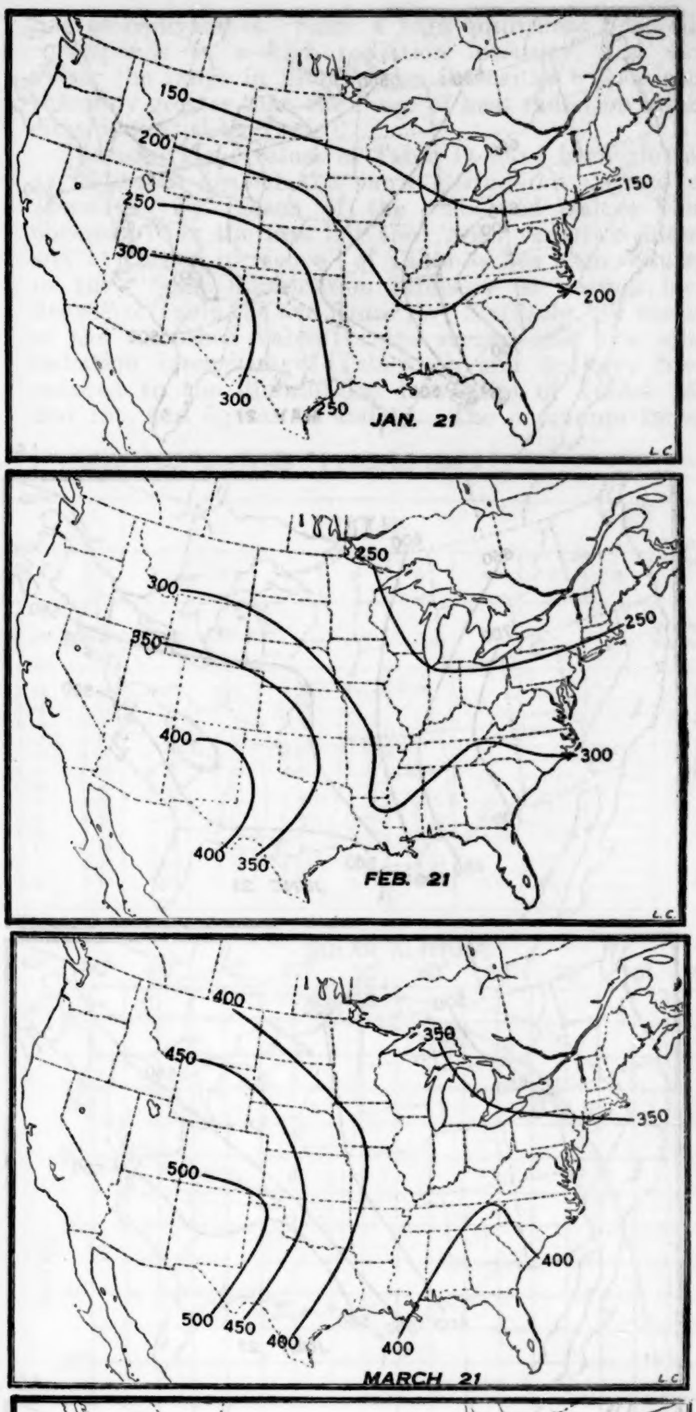


FIGURE 11.—Average daily totals of radiation received on a horizontal surface. (Gram calories per minute per square centimeter.)

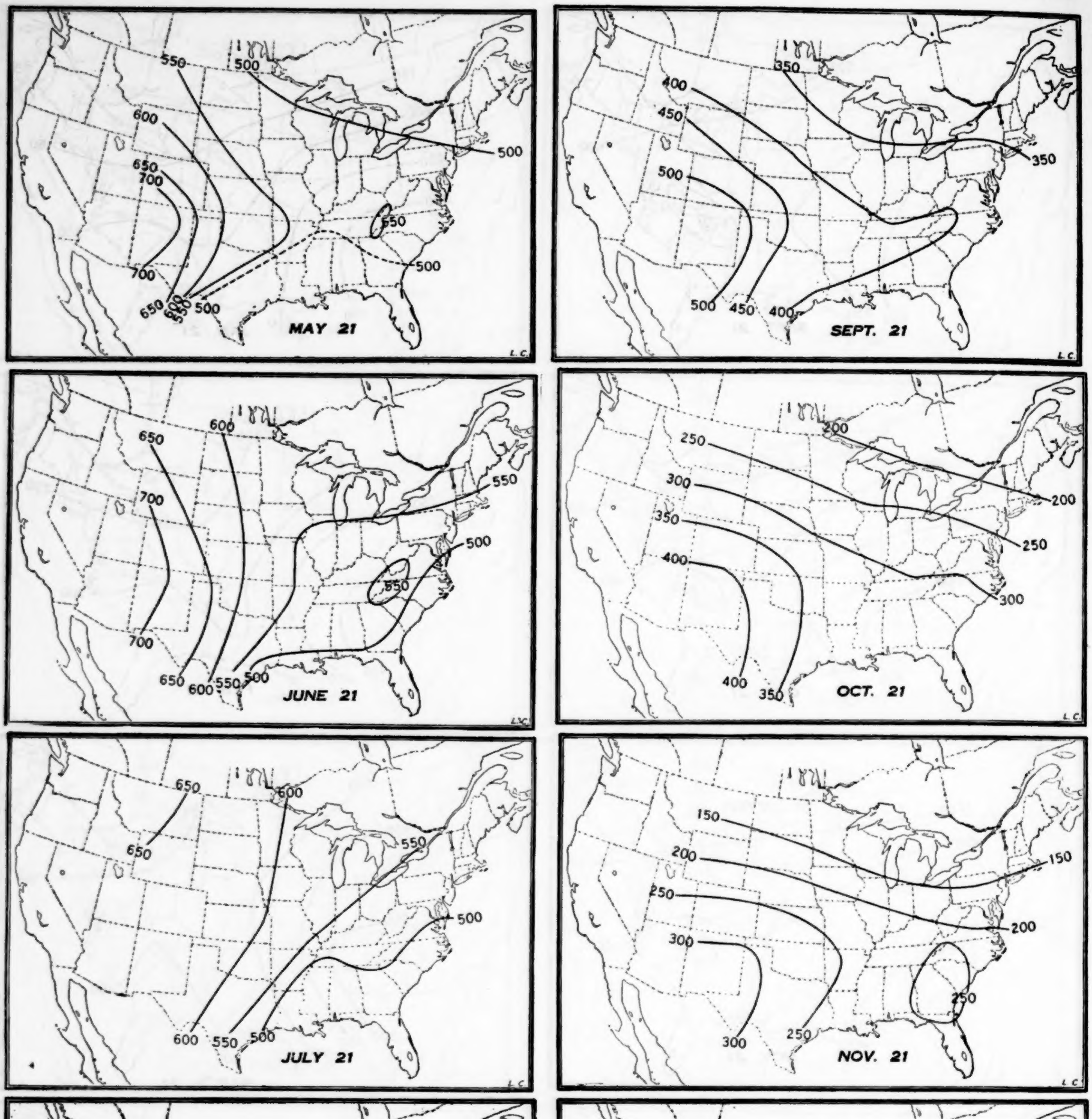


FIGURE 11.—Average daily totals of radiation received on a horizontal surface—Continued. (Gram calories per minute per square centimeter.)

The solar radiation intensities upon these slopes have been computed upon the assumption that at normal incidence the intensity is as given in Table 5c for latitude 37° 46′, increased by 1 per cent for the increased elevation at Wagon Wheel Gap. The results are given in Table 13.

On slopes A–2 and B–2, where the radiation intensity is high throughout the year, the snow that falls is evaporated many days earlier than on slopes A–1 and B–1, which receive no direct solar radiation in midwinter, and a greatly reduced amount throughout the year.

Table 13 indicates a shorter period of sunshine before noon than after noon on slope A–1, and a shorter period after noon than before noon on the other three slopes, except on slopes A–1 and B–1 from about the middle of May to the end of July.

line of equivalents. Since a high equivalent generally corresponds to a high radiation intensity, and vice versa, the range in illumination intensities will be considerably greater than the range of heat radiation intensities indicated by Table 6.

The equivalent values of Table 14 have been plotted as ordinates against the sun's altitude in degrees as abscissas. By means of the smoothed values thus obtained from the first line the "Solar radiation intensity at normal incidence" of Table 5a has been reduced to the "Solar illumination intensity at normal incidence" of Table 15a and figure 13. Similarly, by means of the smoothed values of the second line, the solar radiation intensities of Tables 5b and 5c have been reduced to the illumination intensities of Tables 15b and 15c, and figures 14 and 15. The maximum inten-

TABLE 13.—*Solar radiation intensity upon slopes at Wagon Wheel Gap, Colo. (Apparent time.)*

Slope.	Date.	A. M. 5	6	7	8	9	10	11	12	P. M. 1	2	3	4	5	6	7	8	Daily total.
		Gr.-cal. per min. per square centimeter.																gr.-cal. per cm.²
A–2	Dec. 21				0.53	0.92	1.08	1.09	0.98	0.77	0.50	0.18						379
	Mar. 21		0.07	0.73	1.11	1.34	1.45	1.44	1.31	1.08	0.77	0.41						588
	June 21	0.12	0.51	0.84	1.12	1.29	1.40	1.39	1.27	1.28	1.07	0.80	0.17					643
B–2	Dec. 21				0.49	0.89	1.06	1.13	1.07	0.89	0.78	0.32	0.03					402
	Mar. 21		0.06	0.63	1.02	1.29	1.44	1.48	1.40	1.20	0.92	0.57	0.21					596
	June 21	0.08	0.41	0.74	1.03	1.25	1.38	1.41	1.34	1.17	0.93	0.64	0.32	0.01				641
A–1	Jan. 21							0.02	0.08	0.08	0.01							11
	Feb. 21					0.06	0.15	0.26	0.32	0.33	0.29	0.22	0.11	0.01				105
	Mar. 21			0.03	0.17	0.32	0.45	0.55	0.60	0.61	0.57	0.49	0.36	0.20	0.01			259
	June 21	0.03	0.28	0.45	0.65	0.82	0.96	1.06	1.11	1.12	1.07	0.98	0.87	0.63	0.42	0.06		608
B–1	Feb. 21				0.04	0.11	0.15	0.17	0.16	0.12	0.05							46
	Mar. 21		0.01	0.17	0.29	0.38	0.44	0.46	0.45	0.40	0.33	0.23	0.11	0.09				181
	June 21	0.15	0.43	0.61	0.74	0.84	0.90	0.93	0.93	0.88	0.80	0.71	0.59	0.45	0.30	0.11		555

LUMINOUS RADIATION.

From the simultaneous measurements of heat and luminous solar radiation intensities made at Mount Weather, Va., in 1913–14 [25] there have been derived the equivalent values given in Table 14. Measurements obtained under very smoky conditions in May, and under unusually hazy conditions in August, 1914, have been disregarded in obtaining the second line of values. With solar altitude 30°, the 26 values obtained for the illumination equivalent have varied between 4,680 and 6,370, or 14 per cent below and 17 per cent above the mean value. Twenty of these values lie between 5,090 and 5,980, or 9 per cent below and 7 per cent above the mean value given in the second

TABLE 14.—*Illumination equivalent of one gram-calory per minute per square centimeter of solar heat energy, with the sun at different altitudes.*

Air mass	1.1	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
Solar altitude	65°.0	42°.7	30.°0	23°.5	19°.3	16°.4	14°.3	12°.6	11°.3	10°.2
	Foot-candles.									
All observations	6,320	5,770	5,490	5,170	4,820	4,780	4,670	4,610	4,600	4,480
Observations on good days only	6,720	6,600	5,580	5,310	5,120	4,780	4,670	4,610	4,600	4,480

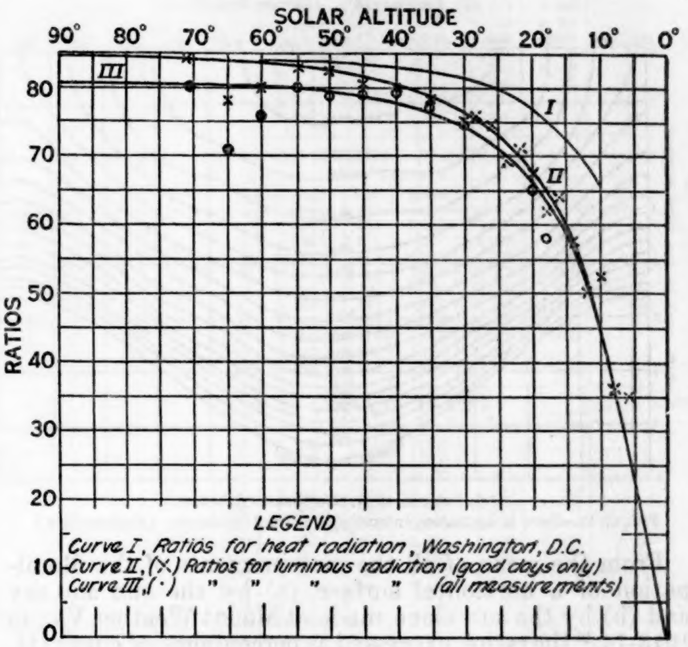
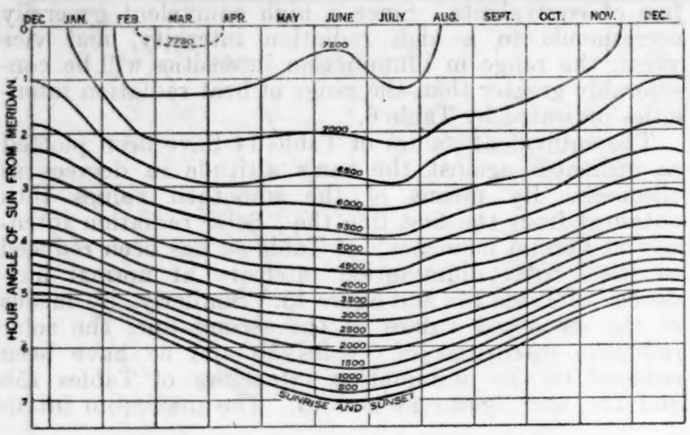


FIGURE 12.—Ratio of direct solar to total radiation (per cent), as received on a horizontal surface.

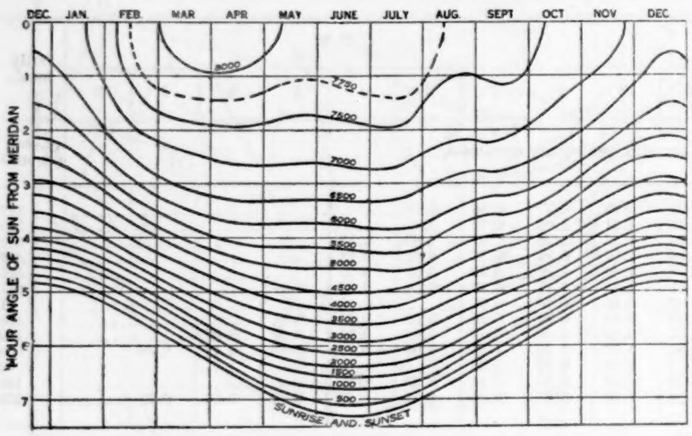
sity of 9,700 foot-candles measured at Mount Weather just before noon on June 30, 1914, is in accord with measurements made in Switzer and by Dorno [26] if we make allowance for the difference in elevation of the two points of observation.

[25] The heat measurements will be found summarized in the Bulletin of the Mount Weather Observatory, vol. 6, pp. 218–219, and in the REVIEW for 1914, vol. 42, pp. 139, 310, and 520; the illumination measurements will be found in the same volume of the REVIEW, p. 652.

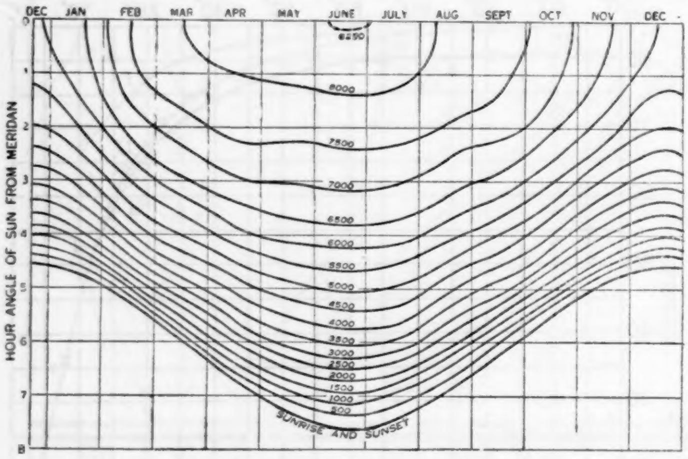
[26] Dorno, C. Physik der Sonnen-und Himmelsstrahlung. Die Wissenschaft, Braunschweig, Bd. 63, S. 46.



(a), Latitude 30°N. (Gulf Coast).



(b), Latitude 36°N. (Eastern States).

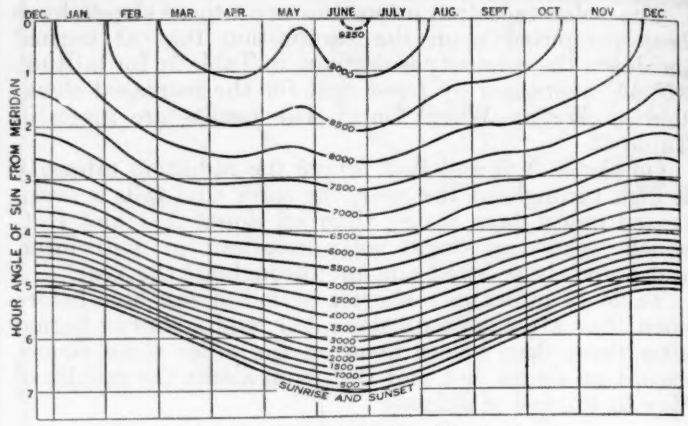


(c), Latitude 42°N. (Northeastern States).

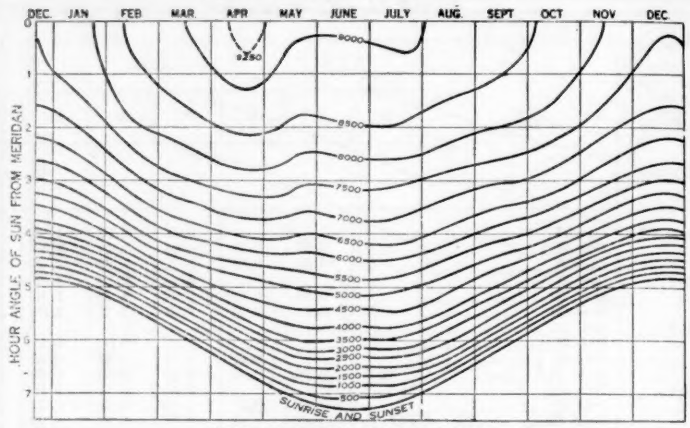
FIGURE 13.—Solar illumination intensity at normal incidence. (Foot-candles.)

From the mean of all the measurements of the illumination of a horizontal surface, (a) by the sun and sky and (b) by the sun alone, made at Mount Weather, Va., in 1913-14,[27] the ratios, expressed as percentages, of curve III, figure 12, have been obtained. Omitting the measurements obtained under unfavorable conditions in May and August, 1914, already referred to, the ratios of curve II, figure 12, have been obtained. There is also shown in figure 12

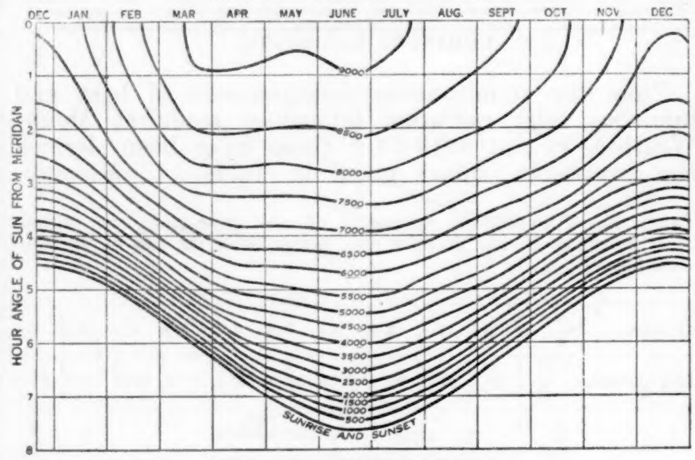
[27] The measurements (a) are summarized in the REVIEW for December, 1914, 12:651' Table 2. The measurements (b) are obtained by subtracting the sky illumination measurements summarized in Table 3, REVIEW reference just cited, from the measurements (a). In obtaining the ratios (b)/(a), here given, the original readings have been used.



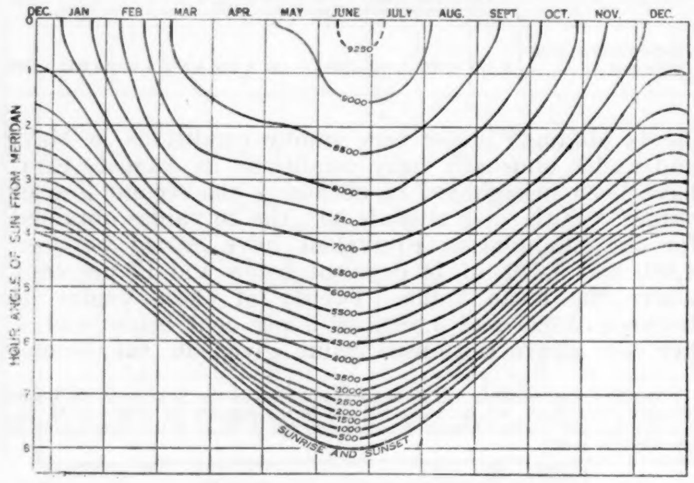
(a), Latitude 30°N. (Southern Plains).



(b), Latitude 36°N. (Central Plains).

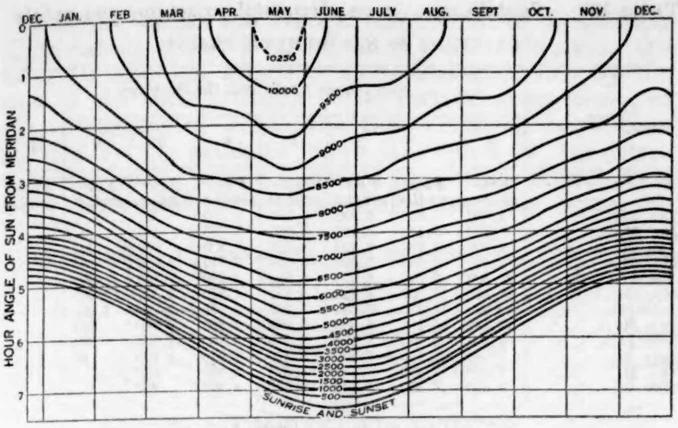


(c), Latitude 42°N. (Central Plains).

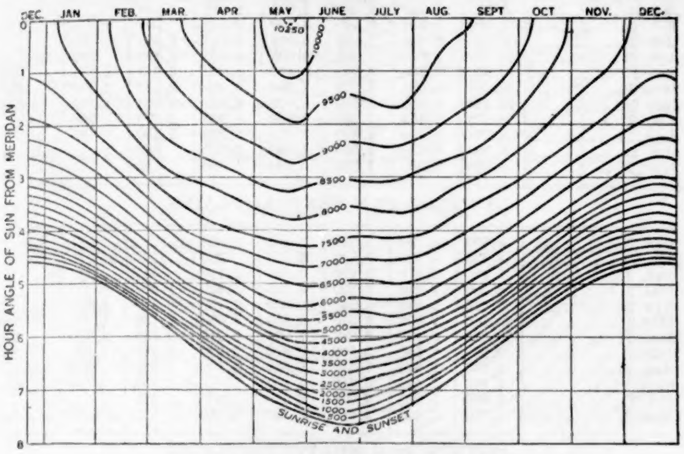


(d), Latitude 48°N. (Northern Plains).

FIGURE 14.—Solar illumination intensity at normal incidence. (Foot-candles).



(a), Latitude 36°N. (Central Plateau).



(b), Latitude 12°N. (Central Plateau).

FIGURE 15.—Solar illumination intensity at normal incidence. (Foot-candles.)

for the purpose of comparison, curve I, derived from the ratios between direct solar and the total heat radiation received on a horizontal surface at Washington, as given in Table 8. As we would expect, the ratio

$$\frac{\text{direct solar radiation}}{\text{total radiation}}$$

is larger than the ratio

$$\frac{\text{direct solar illumination}}{\text{total illumination}},$$

and the percentage difference increases with the zenith distance of the sun. Or, with increase in the sun's zenith distance, the percentage of the total illumination on a horizontal surface received from the sky is increasingly greater than the percentage of total heat radiation received from the same source.

TABLE 15a.—*Solar illumination intensity at normal incidence.*

LATITUDE 30° N. GULF COAST.

Date.	Sun's hour angle from the meridian.							
	0	1	2	3	4	5	6	7
	Foot-candles.	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*
Dec. 21	6,760	6,510	5,900	4,690	3,060	460	......	......
Jan. 21	7,120	6,930	6,360	5,120	3,350	920	......	......
Feb. 21	7,780	7,650	7,080	6,020	4,320	2,450	......	......
Mar. 21	7,870	7,660	7,160	6,300	4,730	2,820	420	......
Apr. 21	7,670	7,560	7,110	6,450	5,290	3,490	1,600	......
May 21	7,600	7,450	7,010	6,310	5,300	3,770	1,820	......
June 21	7,590	7,420	7,030	6,390	5,400	3,930	2,130	......
July 21	7,750	7,590	7,150	6,490	5,420	3,930	2,140	......
Aug. 21	7,420	7,300	6,850	6,100	4,900	3,300	1,470	......
Sept. 21	7,450	7,240	6,860	6,020	4,640	2,680	420	......
Oct. 21	7,220	7,040	6,540	5,520	3,960	2,100	......	......
Nov. 21	7,060	6,820	6,180	5,070	3,300	880	......	......

TABLE 15a.—*Solar illumination intensity at normal incidence*—Contd.

LATITUDE 36° N. EASTERN UNITED STATES.

Date.	Sun's hour angle from the meridian.							
	0	1	2	3	4	5	6	7
	Foot-candles.	*Foot. candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*
Dec. 21	6,660	6,360	5,650	4,430	2,680	......	......	......
Jan. 21	7,000	6,750	6,130	4,920	3,120	......	......	......
Feb. 21	7,890	7,750	7,180	6,060	4,390	2,100	......	......
Mar. 21	8,170	7,960	7,460	6,530	5,130	3,200	420	......
Apr. 21	8,100	7,980	7,470	6,870	5,700	4,040	2,130	......
May 21	7,950	7,780	7,410	6,710	5,760	4,390	2,680	430
June 21	7,960	7,820	7,450	6,810	5,810	4,510	2,780	510
July 21	7,990	7,850	7,480	6,800	5,820	4,450	2,780	430
Aug. 21	7,670	7,480	7,050	6,340	5,220	3,740	1,930	......
Sept. 21	7,680	7,550	7,120	6,320	4,930	3,070	430	......
Oct. 21	7,420	7,220	6,660	5,620	4,040	2,010	......	......
Nov. 21	7,060	6,800	6,170	4,910	3,120	......	......	......

LATITUDE 42° N. NORTHEASTERN UNITED STATES.

Date.	0	1	2	3	4	5	6	7
Dec. 21	5,930	5,650	4,970	3,710	1,690	......	......	......
Jan. 21	6,500	6,240	5,600	4,410	2,600	......	......	......
Feb. 21	7,650	7,510	6,840	5,760	4,440	1,680	......	......
Mar. 21	8,050	7,870	7,370	6,450	5,130	3,300	460	......
Apr. 21	8,220	8,050	7,680	7,030	5,940	4,390	2,510	......
May 21	8,220	8,090	7,660	7,030	6,200	4,880	3,370	800
June 21	8,270	8,140	7,780	7,150	6,220	5,080	3,560	1,500
July 21	8,220	8,090	7,660	7,040	6,270	4,940	3,480	810
Aug. 21	7,880	7,740	7,330	6,620	5,560	4,100	2,080	......
Sept. 21	7,750	7,570	7,240	6,300	5,000	3,260	430	......
Oct. 21	7,120	7,000	6,440	5,350	3,770	1,430	......	......
Nov. 21	6,490	6,240	5,600	4,360	2,350	......	......	......

4390 – 8
5070 – 9
5650 – 10
5520 – 12
6260 – 12
5780 – 14
5960 – 14
5810 – 14
5900 – 12
5370 – 12
5180 – 10
5010 – 8

TABLE 15b.—*Solar illumination intensity at normal incidence.*

LATITUDE 30° N. SOUTHERN PLAINS.

Date.	Sun's Hour Angle from the Meridian.							
	0	1	2	3	4	5	6	7
	Foot-candles.	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*
Dec. 21	7,860	7,700	7,150	6,040	4,190	570	......	......
Jan. 21	8,220	8,060	7,480	6,470	4,620	1,140	......	......
Feb. 21	8,900	8,710	8,110	7,220	5,680	2,970	......	......
Mar. 21	9,170	8,980	8,360	7,590	6,250	3,970	490	......
Apr. 21	9,230	9,060	8,520	7,620	6,440	4,480	2,060	......
May 21	9,040	8,810	8,340	7,540	6,650	4,860	2,590	......
June 21	9,290	9,070	8,580	7,770	6,690	5,190	3,240	......
July 21	9,180	8,960	8,490	7,660	6,720	4,930	2,780	......
Aug. 21	8,810	8,650	8,120	7,270	6,090	4,380	2,140	......
Sept. 21	8,790	8,610	8,010	7,110	5,730	3,460	460	......
Oct. 21	8,510	8,340	7,810	6,890	5,310	2,660	......	......
Nov. 21	8,220	8,060	7,480	6,470	4,610	1,140	......	......

LATITUDE 36° N. CENTRAL PLAINS.

Date.	0	1	2	3	4	5	6	7
Dec. 21	7,560	7,340	6,760	5,510	3,290	......	......	......
Jan. 21	7,920	7,770	7,210	6,060	4,100	......	......	......
Feb. 21	8,740	8,580	7,990	7,140	5,500	2,630	......	......
Mar. 21	9,050	8,880	8,370	7,570	6,270	4,060	520	......
Apr. 21	9,350	9,180	8,640	7,850	6,700	4,900	2,520	......
May 21	9,050	8,850	8,410	7,580	6,540	5,070	3,660	490
June 21	9,050	8,920	8,490	7,700	6,730	5,320	3,430	660
July 21	9.120	8,920	8,490	7,640	6,610	5,130	3,710	530
Aug. 21	8,830	8,660	8,140	7,320	6,240	4,490	2,480	......
Sept. 21	8,690	8,520	7,960	7,110	5,690	3,520	460	......
Oct. 21	8,300	8,150	7,630	6,690	5,050	2,340	......	......
Nov. 21	7,920	7,710	7,150	6,050	4,040	......	......	......

LATITUDE 42° N. CENTRAL PLAINS.

Date.	0	1	2	3	4	5	6	7
Dec. 21	7,040	6,850	6,150	4,850	2,120	......	......	......
Jan. 21	7,540	7,320	6,790	5,540	3,200	......	......	......
Feb. 21	8,500	8,350	7,780	6,860	5,170	1,940	......	......
Mar. 21	9,140	8,990	8,520	7,740	6,460	4,320	490	......
Apr. 21	9,150	8,980	8,550	7,820	6,860	5,290	3,110	......
May 21	9,100	8,920	8,500	7,760	6,890	5,480	3,700	1,110
June 21	9,180	9,020	8,590	7,920	6,970	5,750	4,060	2,120
July 21	9,030	8,870	8,450	7,770	6,830	5,490	3,670	1,120
Aug. 21	8,710	8,540	8,130	7,360	6,320	4,750	2,740	......
Sept. 21	8,550	8,390	7,880	7,030	5,700	3,560	460	......
Oct. 21	8,010	7,870	7,450	6,480	4,720	1,770	......	......
Nov. 21	7,520	7,320	6,730	5,440	3,250	......	......	......

LATITUDE 48° N. NORTHERN PLAINS.

Date.	0	1	2	3	4	5	6	7
Dec. 21	6,160	5,980	5,170	3,520	530	......	......	......
Jan. 21	6,890	6,630	5,950	4,630	1,890	......	......	......
Feb. 21	7,990	7,780	7,280	6,440	4,600	1,250	......	......
Mar. 21	8,920	8,720	8,280	7,490	6,250	4,120	530	......
Apr. 21	8,960	8,810	8,440	7,820	6,840	5,430	3,600	......
May 21	9,040	8,880	8,500	7,930	7,030	5,820	4,160	2,170
June 21	9,340	9,190	8,800	8,220	7,350	6,270	4,740	3.070
July 21	9,180	9,090	8,640	8,000	7,150	5,900	4,320	2,260
Aug. 21	8,800	8,640	8,190	7,590	6,570	5,140	3,520	......
Sept. 21	8,400	8,190	7,790	6,900	5,620	3,560	490	......
Oct. 21	7,640	7,450	6,990	6,020	4,110	860	......	......
Nov. 21	6,840	6,580	5,950	4,590	1,890	......	......	......

TABLE 15c.—*Solar illumination intensity at normal incidence.*

LATITUDE 36° N. CENTRAL PLATEAU.

Date.	Sun's Hour Angle from the Meridian.							
	0	1	2	3	4	5	6	7
	Foot-candles.	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*
Dec. 21	8,340	8,170	7,660	6,400	4,020			
Jan. 21	8,720	8,560	8,030	6,960	4,820			
Feb. 21	9,170	9,000	8,510	7,630	6,090	2,930		
Mar. 21	9,890	9,760	9,230	8,440	7,230	5,050	600	
Apr. 21	10,100	9,980	9,340	8,520	7,420	5,860	2,990	
May 21	10,390	10,220	9,720	8,880	7,760	6,450	4,720	570
June 21	9,880	9,670	9,220	8,580	7,550	6,280	4,370	820
July 21	9,740	9,600	9,150	8,320	7,310	6,100	3,880	530
Aug. 21	9,500	9,320	8,780	8,000	6,910	5,410	2,870	
Sept. 21	9,470	9,290	8,690	7,860	6,600	4,720	570	
Oct. 21	9,030	8,870	8,270	7,340	5,790	2,540		
Nov. 21	8,720	8,490	8,030	6,960	4,820			

LATITUDE 42° N. CENTRAL PLATEAU.

Date.	0	1	2	3	4	5	6	7
Dec. 21	7,740	7,540	6,850	5,450	2,450			
Jan. 21	8,200	7,970	7,410	6,120	3,710			
Feb. 21	8,730	8,640	8,120	7,180	5,640	1,980		
Mar. 21	9,530	9,360	8,880	8,140	7,050	4,920	570	
Apr. 21	9,800	9,630	9,120	8,420	7,370	5,910	3,420	
May 21	10,250	10,060	9,540	8,760	7,800	6,600	5,060	1,590
June 21	9,860	9,680	9,250	8,490	7,620	6,400	4,640	2,540
July 21	9,980	9,810	9,360	8,580	7,700	6,560	4,750	1,600
Aug. 21	9,570	9,390	8,950	8,250	7,210	5,820	3,350	
Sept. 21	9,420	9,130	8,610	7,880	6,690	4,880	570	
Oct. 21	8,600	8,400	7,900	7,010	5,430	1,610		
Nov. 21	8,180	7,970	7,410	6,160	3,670			

TABLE 16a.—*Total illumination on a horizontal surface from sun and sky*.

LATITUDE 30° N. GULF COAST.

Date.	Sun's Hour Angle from the Meridian.							
	0	1	2	3	4	5	6	7
	Foot-candles.	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*
Dec. 21	5,240	4,840	3,910	2,510	1,210	66		
Jan. 21	5,880	5,510	4,520	2,970	1,370	234		
Feb. 21	7,420	7,060	5,850	4,140	2,190	717		
Mar. 21	8,530	8,040	6,770	5,030	2,890	1,120	58	
Apr. 21	9,020	8,680	7,440	5,730	3,640	1,730	474	
May 21	9,290	8,870	7,670	5,920	4,010	2,080	606	
June 21	9,340	8,910	7,790	6,110	4,190	2,270	800	44
July 21	9,490	9,050	7,840	6,110	4,110	2,200	748	
Aug. 21	8,720	8,520	7,180	5,430	3,450	1,640	443	
Sept. 21	8,110	7,620	6,520	4,800	2,850	1,070	66	
Oct. 21	6,870	6,480	5,400	3,790	2,000	653		
Nov. 21	5,830	5,430	4,400	2,930	1,360	222		

LATITUDE 36° N. EASTERN UNITED STATES.

Date.	0	1	2	3	4	5	6	7
Dec. 21	4,510	4,190	3,300	2,050	864			
Jan. 21	5,170	4,810	3,880	2,510	1,110	50		
Feb. 21	6,880	6,540	5,460	3,820	2,030	616		
Mar. 21	8,300	7,790	6,630	4,910	2,980	1,230	60	
Apr. 21	9,200	8,820	7,550	5,950	3,940	2,010	660	
May 21	9,500	9,050	7,950	6,260	4,390	2,380	1,010	68
June 21	9,650	9,250	8,150	6,490	4,560	2,670	1,130	130
July 21	9,570	9,150	8,050	6,360	4,440	2,560	1,060	72
Aug. 21	8,730	8,280	7,130	5,490	3,620	1,870	590	
Sept. 21	7,850	7,460	6,370	4,780	2,920	1,190	70	
Oct. 21	6,460	6,090	5,020	3,540	1,850	586		
Nov. 21	5,200	4,830	3,910	2,500	1,100	50		

LATITUDE 42° NORTHEASTERN UNITED STATES.

Date.	0	1	2	3	4	5	6	7
Dec. 21	3,490	3,180	2,470	1,440	467			
Jan. 21	4,190	3,880	3,090	1,920	810			
Feb. 21	6,040	5,720	4,710	3,260	1,840	470		
Mar. 21	7,560	7,170	6,120	4,550	2,800	1,220	60	
Apr. 21	8,880	8,450	7,390	5,860	4,020	2,180	810	
May 21	9,490	9,130	8,000	6,430	4,660	2,860	1,360	215
June 21	9,740	9,370	8,340	6,740	4,910	3,140	1,560	428
July 21	9,500	9,160	8,010	6,460	4,710	2,980	1,450	218
Aug. 21	8,530	8,190	7,080	5,540	3,770	2,050	667	
Sept. 21	7,320	6,940	6,040	4,470	2,770	1,220	70	
Oct. 21	5,580	5,310	4,400	3,020	1,560	390		
Nov. 21	4,180	3,840	3,080	1,910	728			

TABLE 16b.—*Total illumination on a horizontal surface from sun and sky.*

LATITUDE 30° N. SOUTHERN PLAINS.

Date.	Sun's Hour Angle from the Meridian.							
	0	1	2	3	4	5	6	7
	Foot-candles.	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*
Dec. 21	5,880	5,550	4,590	3,150	1,580	66		
Jan. 21	6,550	6,170	5,140	3,660	1,870	290		
Feb. 21	8,200	7,760	6,490	4,770	2,820	920		
Mar. 21	9,520	9,060	7,640	5,840	3,710	1,550	58	
Apr. 21	10,360	9,940	8,570	6,550	4,380	2,170	608	
May 21	10,510	10,009	8,730	6,850	4,870	2,620	905	
June 21	10,870	10,370	9,080	7,160	5,010	2,920	1,200	44
July 21	10,680	10,180	8,900	6,980	4,880	2,680	972	
Aug. 21	9,890	9,520	8,170	6,270	4,160	2,130	634	
Sept. 21	9,160	8,720	7,350	5,490	3,410	1,370	66	
Oct. 21	7,830	7,410	6,230	4,570	2,630	826		
Nov. 21	6,560	6,200	5,140	3,650	1,860	287		

LATITUDE 36° N. CENTRAL PLAINS.

Date.	0	1	2	3	4	5	6	7
Dec. 21	5,000	4,700	3,830	2,500	1,050			
Jan. 21	5,650	5,350	4,440	3,030	1,450	50		
Feb. 21	7,370	7,000	5,880	4,360	2,500	770		
Mar. 21	8,860	8,390	7,160	5,510	3,540	1,550	60	
Apr. 21	10,170	9,710	8,400	6,600	4,520	2,390	780	
May 21	10,320	9,850	8,660	6,830	4,820	2,840	1,370	68
June 21	10,440	10,070	8,900	7,090	5,090	3,110	1,370	170
July 21	10,410	9,950	8,770	6,900	4,890	2,870	1,390	72
Aug. 21	9,610	9,180	7,930	6,140	4,200	2,190	760	
Sept. 21	8,540	8,110	6,890	5,210	3,270	1,350	70	
Oct. 21	6,980	6,630	5,590	4,090	2,270	680		
Nov. 21	5,650	5,290	4,380	3,020	1,430	50		

LATITUDE 42° N. CENTRAL PLAINS.

Date.	0	1	2	3	4	5	6	7
Dec. 21	4,030	3,780	2,980	1,870	630			
Jan. 21	4,720	4,420	3,650	2,370	995			
Feb. 21	6,480	6,170	5,180	3,790	2,110	540		
Mar. 21	8,300	7,900	6,820	5,280	3,420	1,590	60	
Apr. 21	9,470	9,060	7,940	6,300	4,490	2,570	1,000	
May 21	10,040	9,620	8,540	6,850	5,060	3,130	1,470	300
June 21	10,320	9,930	8,880	7,230	5,310	3,460	1,750	600
July 21	9,990	9,580	8,500	6,890	5,020	3,140	1,470	300
Aug. 21	9,030	8,630	7,580	5,850	4,160	2,320	880	
Sept. 21	7,810	7,420	6,350	4,810	3,000	1,330	70	
Oct. 21	6,070	5,760	4,920	3,570	1,930	480		
Nov. 21	4,700	4,420	3,610	2,330	1,000			

LATITUDE 48° N. NORTHERN PLAINS.

Date.	0	1	2	3	4	5	6	7
Dec. 21	2,960	2,750	2,090	1,140	90			
Jan. 21	3,680	3,420	2,710	1,680	513			
Feb. 21	5,400	5,090	4,310	3,200	1,680	318		
Mar. 21	7,390	7,020	6,110	4,730	3,120	1,450	60	
Apr. 21	8,720	8,370	7,410	6,020	4,340	2,630	1,200	
May 21	9,550	9,170	8,200	6,810	5,090	3,360	1,660	620
June 21	10,120	9,750	8,770	7,320	5,560	3,840	2,180	990
July 21	9,710	9,430	8,360	6,890	5,190	3,420	1,830	666
Aug. 21	9,590	8,230	7,210	5,860	4,190	2,500	1,180	
Sept. 21	7,020	6,630	5,780	4,400	2,830	1,260	75	
Oct. 21	5,150	4,860	4,130	2,980	1,500	226		
Nov. 21	3,670	3,390	2,710	1,670	510			

TABLE 16c.—*Total illumination from sun and sky on a horizontal surface.*

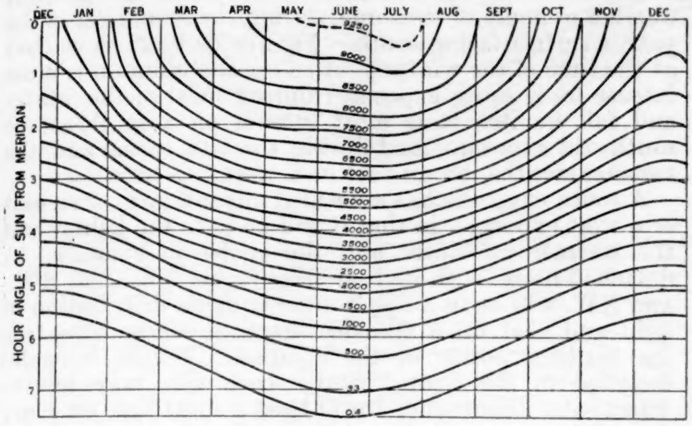
LATITUDE 36° N. CENTRAL PLATEAU.

Date.	Hour Angle of the Sun from the Meridian.							
	0	1	2	3	4	5	6	7
	Foot-candles.	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*	*Foot-candles.*
Dec. 21	5,520	5,220	4,340	2,970	1,300			
Jan. 21	6,210	5,880	4,900	3,470	1,710	50		
Feb. 21	7,740	7,350	6,260	4,660	2,770	853		
Mar. 21	9,670	9,210	7,940	6,140	3,820	1,930	60	
Apr. 21	10,980	10,550	9,100	7,140	5,010	2,860	930	
May 21	11,850	11,380	10,010	8,000	5,710	3,600	1,760	68
June 21	11,510	10,700	9,670	7,900	5,730	3,670	1,930	210
July 21	11,130	10,700	9,460	7,520	5,410	3,420	1,470	72
Aug. 21	10,330	9,870	8,540	6,710	4,660	2,640	880	
Sept. 21	9,310	8,840	7,510	5,690	3,790	1,810	70	
Oct. 21	7,600	7,220	6,060	4,490	2,610	743		
Nov. 21	6,210	5,820	4,930	3,470	1,620	50		

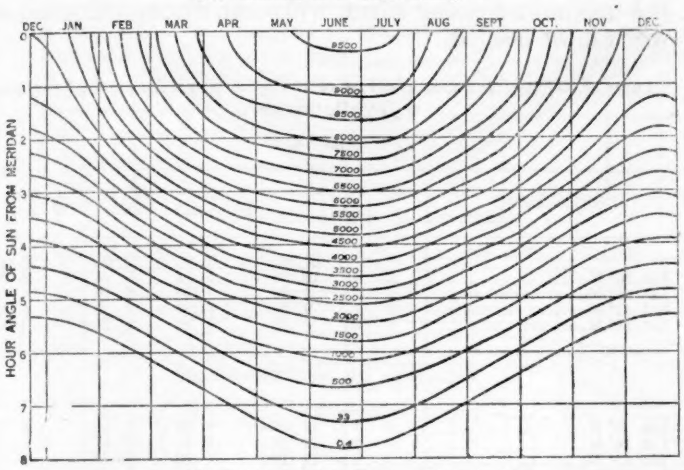
LATITUDE 42° N. CENTRAL PLATEAU.

Date.	0	1	2	3	4	5	6	7
Dec. 21	4,430	4,160	3,330	2,100	675			
Jan. 21	5,140	4,810	3,980	2,630	1,150			
Feb. 21	6,660	6,380	5,400	3,960	2,290	552		
Mar. 21	8,650	8,330	7,120	5,570	3,770	1,810	60	
Apr. 21	10,120	9,710	8,470	6,790	4,820	2,880	1,100	
May 21	11,310	10,850	9,590	7,730	5,710	3,770	2,020	445
June 21	11,090	10,640	9,520	7,740	5,810	3,810	2,010	723
July 21	11,030	10,610	9,410	7,610	5,650	3,760	1,910	431
Aug. 21	9,930	9,510	8,340	6,670	4,740	2,850	1,080	
Sept. 21	8,600	8,090	6,940	5,410	3,610	1,830	70	
Oct. 21	6,520	6,160	5,220	3,870	2,220	435		
Nov. 21	5,110	4,810	3,970	2,650	1,140			

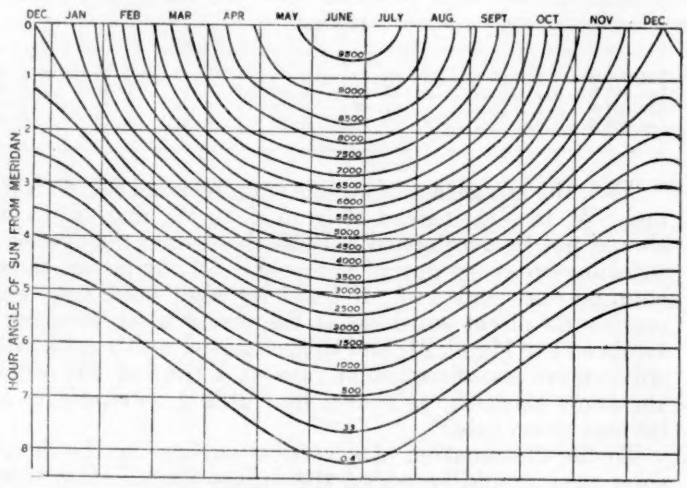
We may obtain the vertical component of direct solar illumination at any hour of the day by multiplying the solar illumination intensity at normal incidence by the sine of the solar altitude. The vertical components of the intensities of Table 15a thus obtained have been divided by the ratios of curve III, figure 12, for corresponding solar altitude, to obtain the "Total illumination on a horizontal surface" of Table 16a, and figure 16.



(a), Latitude 30°N. (Gulf Coast).



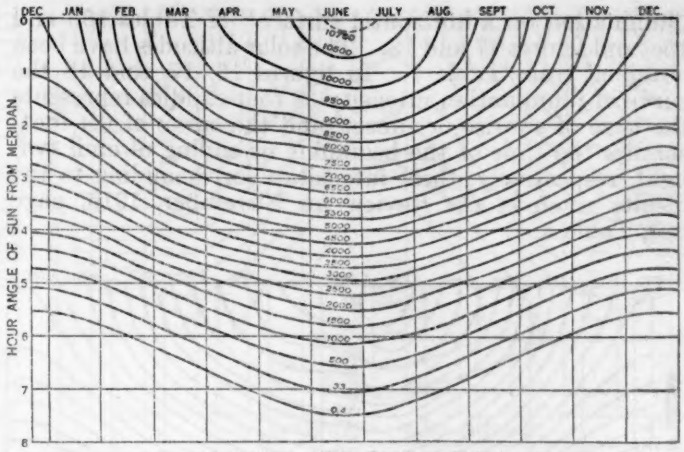
(b), Latitude 36°N. (Eastern States).



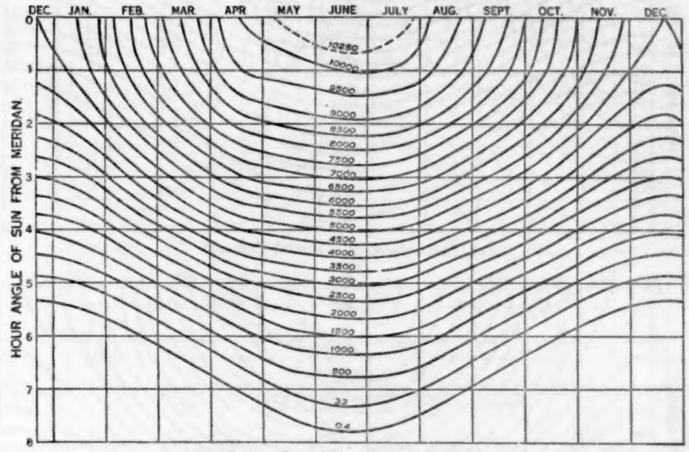
(c), Latitude 42°N. (Northeastern States).

FIGURE 16.—Total illumination on a horizontal surface. (Foot-candles.)

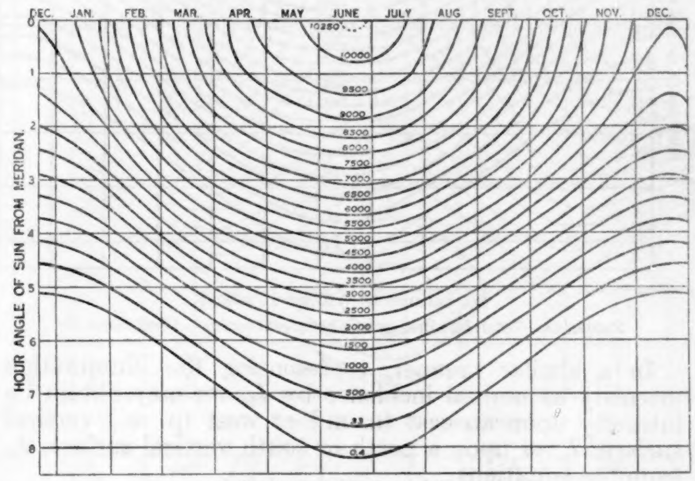
Similarly, the vertical components of the illumination intensities of Table 15b and 15c have been divided by the ratios obtained from curve II, to obtain the "Total



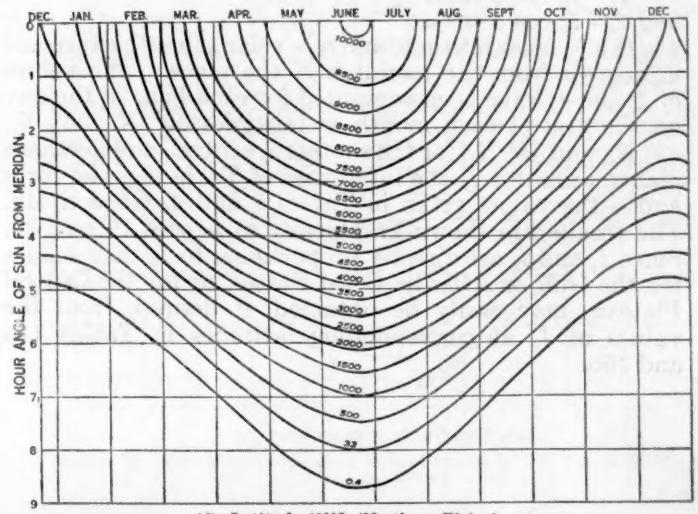
(a), Latitude 30°N. (Southern Plains).



(b), Latitude 36°N. (Central Plains).



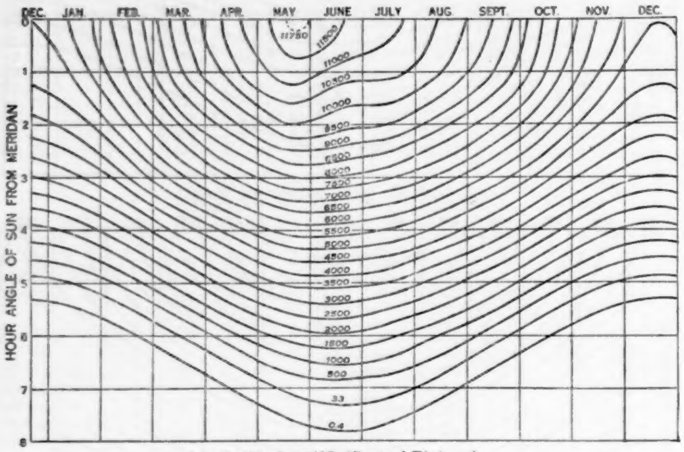
(c), Latitude 42°N. (Central Pl ns).



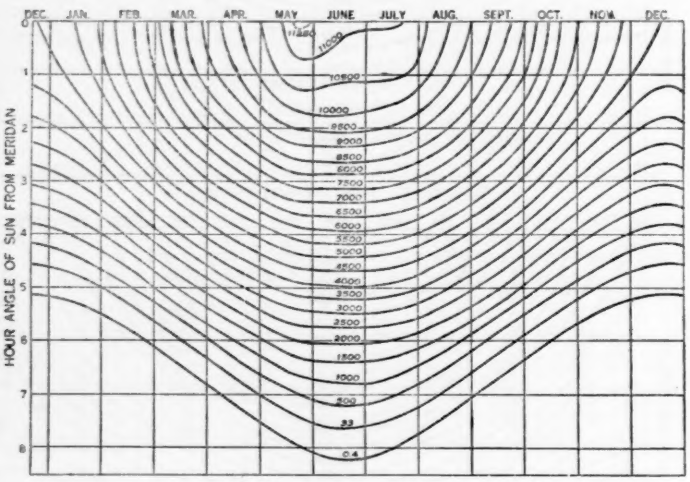
(d), Latitude 48°N. (Northern Plains).

FIGURE 17.—Total illumination on a horizontal surface. (Foot-candles.)

illumination on a horizontal surface" of Tables 16b and 16c, and figures 17 and 18. The solar altitudes have been obtained from Table 1. In figures 16, 17, and 18 the curve of illumination intensity 33 foot-candles represents the time of sunrise or sunset, and the curve of 0.4 foot-candles the time of the beginning or ending of civil twilight, respectively, these intensities corresponding to the results given in the Review for November, 1916, page 620, Table 5.



(a), Latitude 36°N. (Central Plateau).



(b), Latitude 42°N. (Central Plateau).

FIGURE 18.—Total illumination on a horizontal surface. (Foot-candles.)

In a similar manner, representing the illumination intensity at normal incidence by I_n, we may obtain its intensity upon an east (a. m.) or west (p. m.) vertical surface, I_e, or upon a north or south vertical surface, I_s, from the equations

$$I_e = I_n \cos a \sin \alpha$$

and $I_s = I_n \cos a \cos \alpha$

where a = solar latitude, and α = solar azimuth expressed in degrees from the meridian of the place. The values of I_e and I_s have been computed for each hour of the day on the 21st of each month at latitudes 30° N., 36° N., 42° N., and 48° N., for the southern, central, and northern plains, using for I_n the intensities of Table 15b and for a and α the values given in Tables 1 and 2, respectively. The results are shown graphically in figures 19 and 20. Since I_e and I_s are directly proportional to I_n their values for the Gulf or Atlantic Coast States, or for the Central Plateau, may easily be obtained, if desired, from the values of I_n at corresponding latitudes in Tables 15a and 15c.

The intensity of solar illumination upon surfaces facing NE., SE., SW., and NW., respectively, has also been computed, and the results are shown graphically in figures 21 and 22.

Table 17 shows the possible hours of direct solar illumination, at the time of the solstices and the equinoxes, on vertical surfaces differently oriented. During the late spring and the summer months a vertical surface facing southeast or southwest will receive the greatest number of hours of sunshine; during the remainder of the year, a surface facing south. Figures 19 to 22 show that at the time of the winter solstice the illumination is most intense on a south exposure; during most of the winter and fall months it is most intense on a southeast or southwest exposure; and during the late spring and the summer months, on an east or a west exposure.

A south exposure has a decided advantage over an east or a west exposure, in that it will be both the lighter and the warmer in winter and the cooler in summer. A detached house with its four sides facing NE., SE., SW., and NW. will have a much more equable distribution of light and heat upon all sides than one whose sides face the cardinal points of the compass. In the latitudes included in the United States each side may receive direct solar illumination for at least a short time on every day in the year, and the maximum illumination, and also the maximim heating effect, will come during the seasons when most needed.

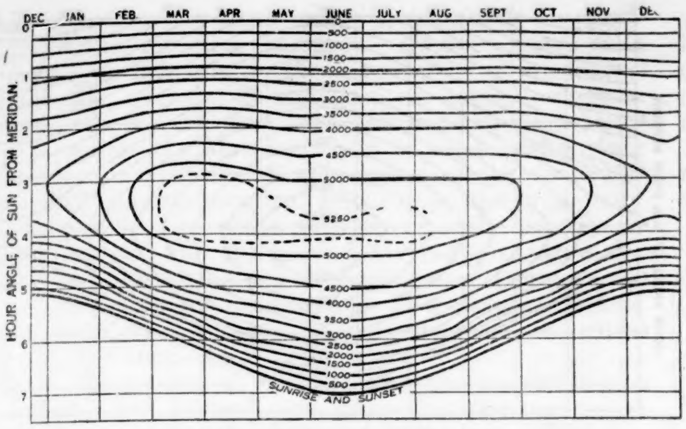
TABLE 17.—*Possible hours of direct solar illumination for vertical surfaces differently oriented.*

Surface facing.	N.	S.	E. (a.m.) W. (p.m.)	SE. or SW.	NE. (a.m.) NW. (p.m.)
DECEMBER 21.					
	H. m.	*H. m.*	*H. m.*	*H. m.*	*H. m.*
Lat. 30° N	0 0	10 08	5 04	8 08	2 00
Lat. 36° N	0 0	9 40	4 50	8 00	1 40
Lat. 42° N	0 0	9 00	4 30	7 48	1 12
Lat. 48° N	0 0	8 22	4 11	7 32	0 50
MARCH 21 OR SEPTEMBER 21.					
Lat. 30° N	0 0	12 08	6 04	7 50	4 18
Lat. 36° N	0 0	12 10	6 05	8 07	4 03
Lat. 42° N	0 0	12 12	6 06	8 20	3 50
Lat. 48° N	0 0	12 14	6 07	8 33	3 41
JUNE 21.					
Lat. 30° N	8 40	5 24	7 02	7 30	6 34
Lat. 36° N	7 28	7 08	7 18	8 10	6 26
Lat. 42° N	7 08	8 08	7 38	8 52	6 24
Lat. 48° N	7 06	8 56	8 01	9 33	6 29

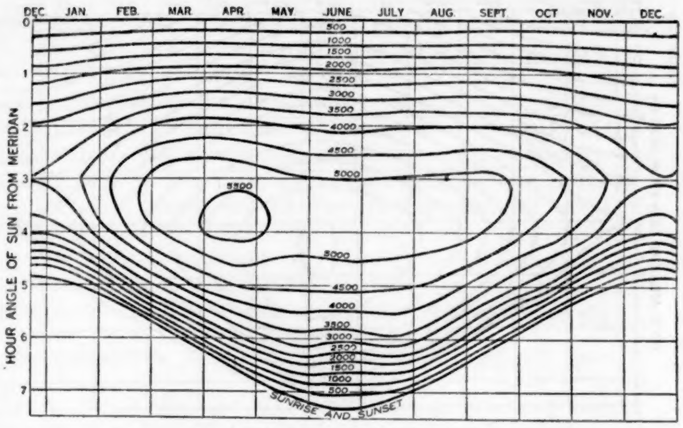
Also, the advantage of streets running from SE. to NW. and SW. to NE. instead of from E. to W. and N. to S. should not be overlooked. Both the former may receive sunshine on every day of the year. Of the latter, those running east and west, if lined by high buildings, will receive no direct sunshine at the street level from September 21 to March 21; and those running north and south will receive the direct solar rays at a time of day when the sun's azimuth, as shown by Table 2, is changing at its maximum rate.[28]

To the illumination of a vertical surface by the direct solar rays should be added the diffuse illumination from the sky, and the reflection of light from the ground and

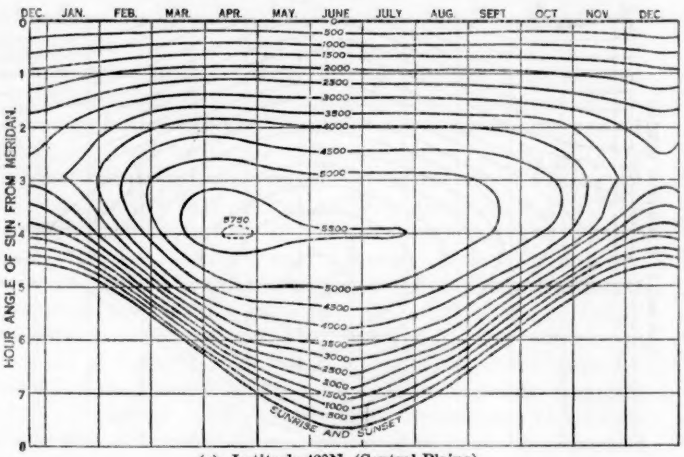
[28] See "Planning Sunlight Cities," by Herbert S. Swan and George W. Tuttle, in The American City Pamphlets, No. 167; The Civic Press, New York. The authors show that north-south streets afford the maximum daylight illumination for high attached buildings, and that detached houses on narrow lots facing on east-west streets are more uniformly lighted on both sides than would be the case if the streets were differently oriented.



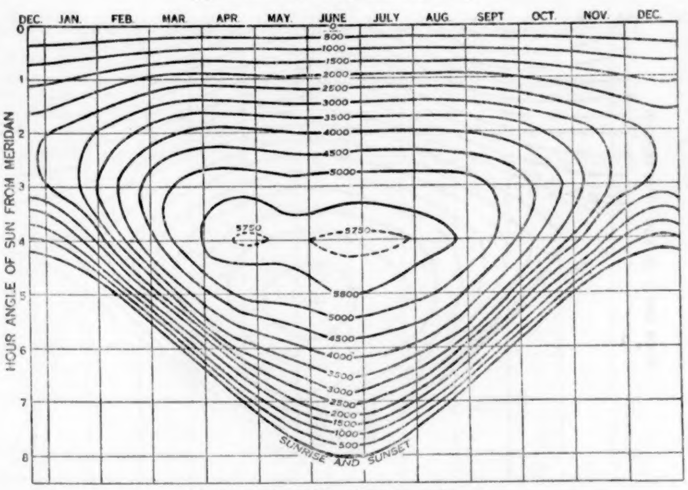
(*a*), Latitude 30°N. (Southern Plains).



(*b*), Latitude 36°N. (Central Plains).

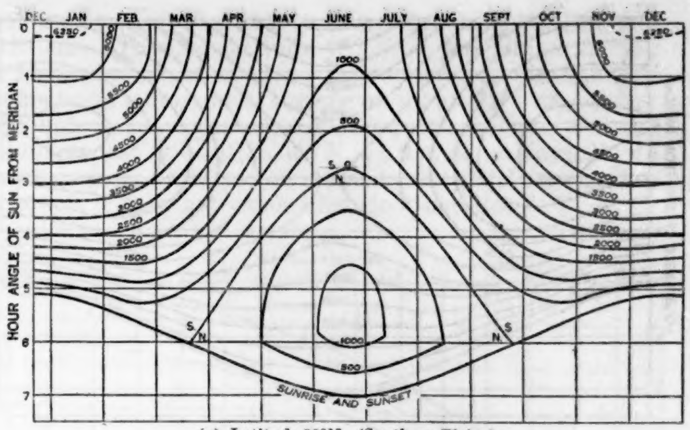


(*c*), Latitude 42°N. (Central Plains).

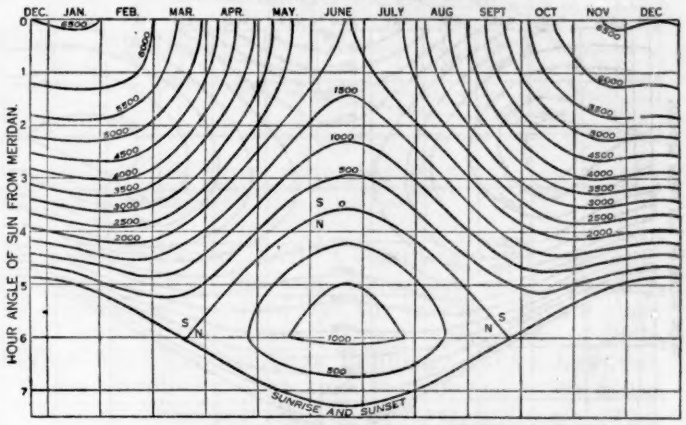


(*d*), Latitude 48°N. (Northern Plains).

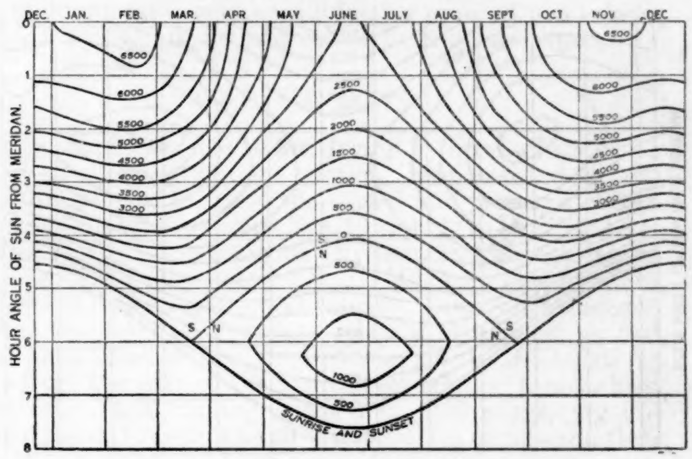
FIGURE 19.—Solar illumination on a vertical surface facing east (a. m.), or west (p. m.), (Foot-candles.)



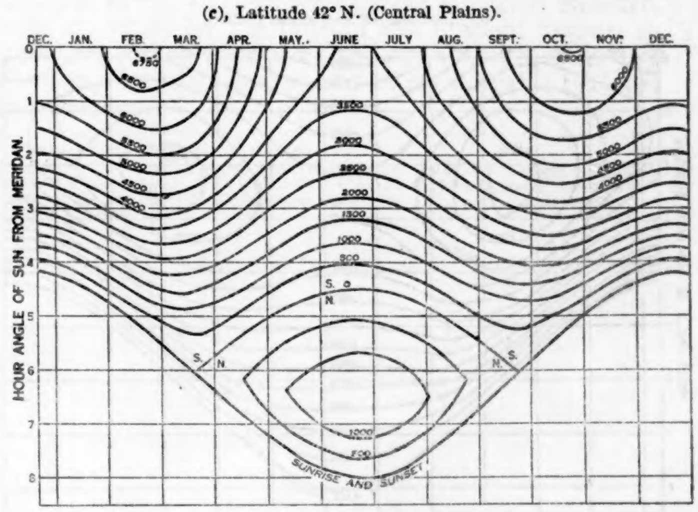
(*a*), Latitude 30°N. (Southern Plains).



(*b*), Latitude 36°N. (Central Plains).

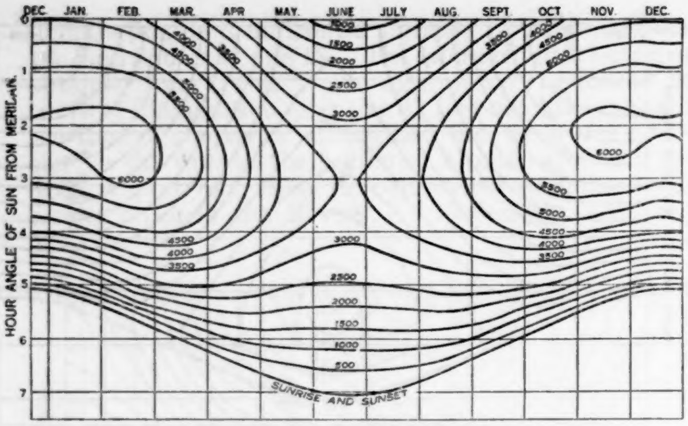


(*c*), Latitude 42° N. (Central Plains).

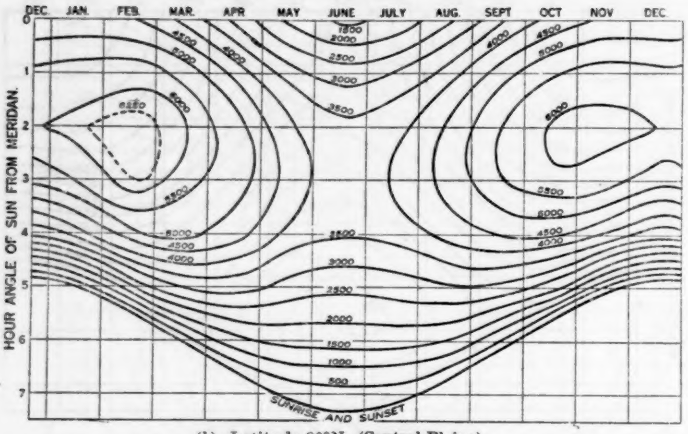


(*d*), Latitude 48°N. (Northern Plains).

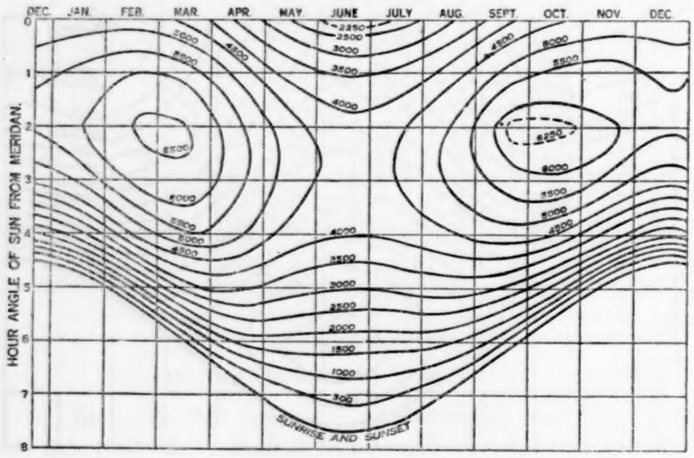
FIGURE 20.—Solar illumination on a vertical surface facing north or south. (Foot-candles.)



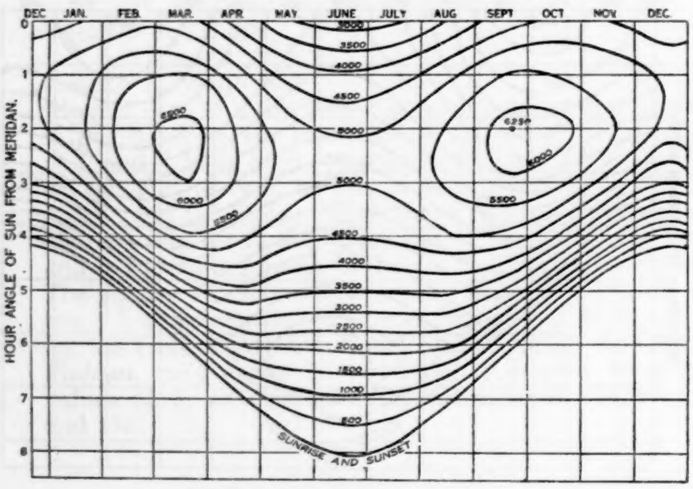
(a), Latitude 30°N. (Southern Plains).



(b), Latitude 36°N. (Central Plains).

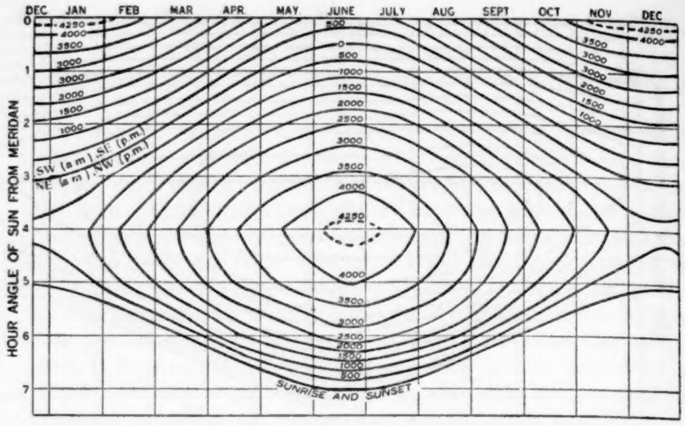


(c), Latitude 42°N. (Central Plains).

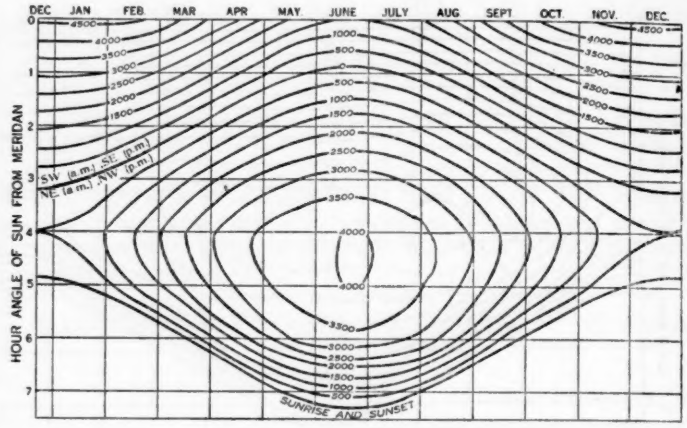


(d), Latitude 48°N. (Northern Plains).

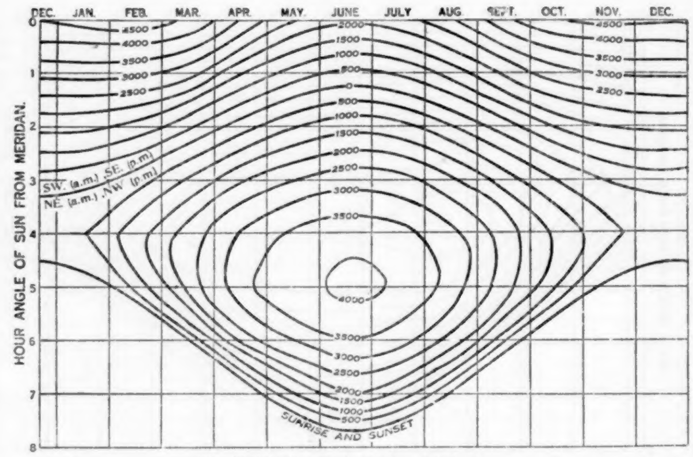
FIGURE 21.—Solar illumination on a vertical surface facing SE. (a. m.) or SW. (p. m.). (Foot-candles.)



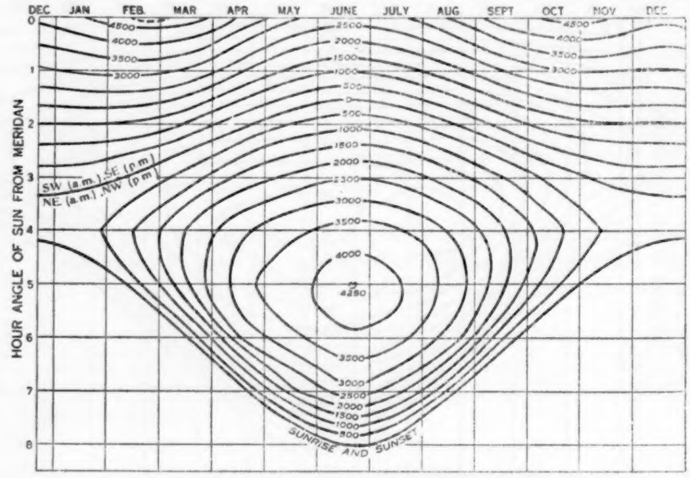
(a), Latitude 30°N. (Southern Plains).



(b), Latitude 36°N. (Central Plains).



(c), Latitude 42°N. (Central Plains).



(d), Latitude 48 °N. (Northern Plains).

FIGURE 22.—Solar illumination on a vertical surface; above zero line, facing SW. (a. m.), or SE. (p. m.); below zero line, facing NE. (a. m.), or NW. (p. m.).

other objects. The latter varies greatly with the character of the reflecting surfaces. Dorno[29] states that at Davos, in Switzerland, the snow cover of winter increases the average illumination of vertical surfaces facing both toward and from the sun (Vorderlich) so that it equals the illumination of a horizontal surface (Oberlicht). With the disappearance of the snow the Vorderlicht diminishes about 25 per cent, and principally on surfaces facing northward; for with the sun at an altitude of 40°, and the ground covered with snow, he found the illumination of a vertical surface facing north to be one-fourth the illumination of a vertical surface facing south, while without the snow cover the proportion was only one-thirteenth.

From the studies of Wiener[30] and the measurements of Abbot[31] and Dorno[32], we know that the unclouded sky has its maximum brightness near the sun. With the sun near the horizon the point of minimum brightness, approximately 90° above the sun, is only about one-tenth as bright as the sky 10° from the sun which, in turn, is only one-tenth as bright as the sky 2° from the sun. With increasing solar altitude the solar distance of this point of minimum diminishes, as also does the ratio of the maximum to the minimum intensity. In general, the sky brightness increases with approach to the horizon. Therefore, we must expect the illumination of vertical surfaces by diffuse light from the sky and reflected light from the earth and other objects to exceed one-half the illumination of a horizontal surface by skylight, and under favorable conditions to equal or even exceed it.

ILLUMINATION INTENSITY WITH AN OVERCAST SKY.

From the Callendar pyrheliometer records of hourly amounts of radiation received on a horizontal surface at Washington, Madison, and Lincoln, on days when no sunshine was recorded by the Marvin sunshine recorder, the average radiation intensity per minute during each hour has been determined, tabulated by months with respect to the sun's altitude at the time of mean radiation intensity for the hour, and the monthly averages for each solar altitude reduced to illumination intensity by multiplying 6,250[33]. Plotting these monthly means of illumination intensity against the corresponding solar altitudes, the smooth curve I, figure 23, is obtained for the Plains States from the Madison and Lincoln records, which are closely in accord, and curve II, for the Atlantic Coast States from the Washington records. From the monthly minimum intensities for the different solar altitudes, Curve III is obtained for the Plains States, and Curve IV for the Atlantic Coast States. With these curves, and the solar altitudes of Table 1, we may determine the average and the minimum illumination that may be expected with an overcast sky at any hour of the day at different latitudes. Thus, at latitude 48° N., in the Plains States, on December 21, at noon, we may expect an illumination intensity on a horizontal surface of about 800 foot-candles although it may not exceed 160 foot-candles. On the Atlantic coast at latutide 36° N., at 9 a. m. on June 21, we may expect an illumination intensity of 1,260 foot-candles, although it may not exceed 300 foot-candles.

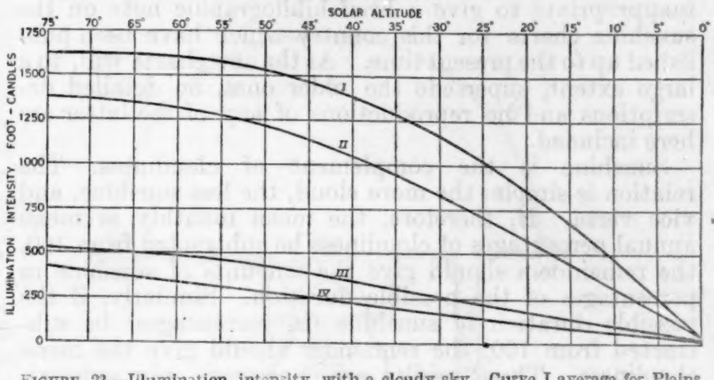


FIGURE 23.—Illumination intensity with a cloudy sky. Curve I average for Plains States. Curve II average for Atlantic Coast States. Curve III Minimum for Plains States. Curve IV Minimum for Atlantic Coast States.

As already shown[34], with a completely overcast sky, and especially with low sun, the illumination intensity may equal or even exceed half the intensity with a clear sky. Therefore the curves of mean values are of little practical use. The curves of minimum values, however, show the illumintion that may be expected when dense rain or snow clouds prevail. If, however, to the screening effect of clouds we add that of dense city smoke, the daylight illumination may be still further reduced, as has been shown by the author and others in previous papers.[35]

ACKNOWLEDGMENTS.

My thanks are due to Mr. Irving F. Hand of the Solar Radiation Investigations section, who assisted in the computation of many of the tables, and prepared practically all the figures except Nos. 10 and 11; to Mr. P. C. Day, Chief of the Climatological Division, and Meteorologists George A. Loveland and Eric R. Miller, in charge of the Weather Bureau stations at Lincoln, Nebr., and Madison, Wis., respectively, for data relative to cloudiness and the percentage of possible sunshine; also to Mr. Miller for reading that part of the manuscript relating to solar heat radiation, and making corrections and suggesting improvements therein; and to the officials in charge and their assistants at the stations where solar radiation measurements are made for the faithful and efficient manner in which they have performed these extra duties, often outside of regular office hours, and at considerable personal inconvienence.

[29] Ibid., p. 111.
[30] *Wiener, Dr. Chr.* Die Helligkeit des Klaren Himmels und die Beleuchtung durch Sonne, Himmel und Rückstrahlung. Abh. die Kaiserl. Leop.-Carol. Deutschen Akad. der Naturforscher. Band 73, Nr. 1, Halle, 1900, Band 91, Nr. 2, Halle, 1909.
[31] *Abbott, C. G.* Annals of the Astrophysical Observatory of the Smithsonian Institution. Vol. 3, 1913, p. 141-151. The direct and scattered radiation of the sun and stars. Astron. Jr., March, 1914, 28: 129-135.
[32] *Dorno, C.* Himmelshelligkeit, Himmelspolarisation und Sonnenintensität in Davos, 1911 bis 1918. Met. Zeit., 36, 1919, S. 109-124.
[33] See MONTHLY WEATHER REVIEW for December, 1914, **42**: 651-652, for the derivation of this factor.

[34] MONTHLY WEATHER REVIEW, loc. cit.
[35] *Kimball, Herbert H.* The meteorological aspect of the smoke problem. MONTHLY WEATHER REVIEW, January, 1914, **42**:29-34. Kimball, Herbert H. and Thiessen, Alfred H. City smoke and daylight illumination intensities. MONTHLY WEATHER REVIEW, May 1917, **45**:205-207.

BIBLIOGRAPHIC NOTE ON SUNSHINE IN THE UNITED STATES.

By ROBERT DE C. WARD.

[Dated: Harvard University, Cambridge, Mass., Dec. 1, 1919.]

In view of the fact that a forthcoming section of the Atlas of American Agriculture will contain a series of new sunshine charts for the United States, it may not be inappropriate to give a brief bibliographic note on the sunshine charts for this country which have been published up to the present time. As the new charts will, to a large extent, supersede the older ones, no detailed descriptions and no reproductions of any of the latter are here included.

Sunshine is the complement of cloudiness. The relation is simple: the more cloud, the less sunshine, and vice versa. If, therefore, the mean monthly or mean annual percentages of cloudiness be subtracted from 100, the remainders should give the amounts of sunshine in percentages of the possible duration. Similarly, if the possible duration of sunshine (in percentages) be subtracted from 100, the remainder should give the mean cloudiness. These results are, however, only approximate.* They may, and often do, differ more or less from the instrumental results obtained by means of sunshine recorders. The amount of cloudiness is based upon estimates, made by eye at certain stated hours during the day. Such estimates are inevitably more or less inaccurate and individual, and are difficult to make when the clouds are near the horizon. Sunshine recorders, on the other hand, while they give a rigidly instrumental record of the duration of bright sunshine, include only a small portion of the sky, and are also less reliable when the sun is low, and its rays are weak. These intrinsic sources of inaccuracy do not, however, in any way seriously interfere with the value of the ordinary sunshine data which are available for many parts of the world.

Sunshine charts are of two classes. They either give (1) the number of hours of bright sunshine, as determined by means of sunshine recorders; or they show (2) the duration of sunshine in percentages of the possible duration. These percentages may be obtained from the total cloudiness, as above noted, or by comparing the total number of hours of bright sunshine as indicated by sunshine recorders with the total possible number of hours, and expressing the results as percentages. When eye observations of cloudiness are available, but sufficient instrumental records of sunshine are lacking, the former method is the one naturally adopted. Sunshine charts of both of the above kinds have been published for the United States.

To the first group belong the chart of mean annual sunshine of North America published by van Bebber in 1896,[1] and a series of charts published by Glaser in 1912.[2] Van Bebber's map, well known because of its having been included in Bartholomew's Atlas of Meteorology, is based upon data collected up to the end of 1895, chiefly those of photographic sunshine recorders and of differential thermometers. The available material was confessedly very inadequate. The maximum number of hours of bright sunshine is given as 3,250, in the southwestern interior. From that area there is a decrease in all directions, especially toward the north and northwest. The line of 2,000 hours runs fairly closely along the northern border of the United States. All the lines are broadly generalized and have mostly an east-west course. Gläser's study of cloudiness and sunshine is by far the most complete which has hitherto appeared in print. His charts show the mean duration of sunshine (in hours) for each month and for the year, and in hours of the day for each month. Records were used for 62 stations with ordinary and for 28 stations with photographic recorders. The chart of mean annual duration of sunshine in hours is based on more complete data than were available when van Bebber's map was prepared. Gläser's map gives more detail, and emphasizes local conditions. The maximum number of hours of bright sunshine (3,500) is found in Arizona and the adjacent portions of southwestern Utah and southeastern Nevada. From here the decrease is marked to the northwest, north, and northeast, and, to a less degree, to the east. The smallest number of hours is below 2,000 on the extreme northwestern coast, and in the northeast, especially over the Great Lakes. The number of hours of bright sunshine, by months, shows a well-defined general increase all over the country from December to July. There is, in other words, a general northward migration of summer conditions as the season advances from winter to mid-summer, summer having the maximum sunshine in most sections, although spring and autumn are the sunniest seasons over small areas. At most stations, also, December has the smallest number of sunny hours and July has the largest. The annual variation in the amounts of sunshine is greatest in the northwest and over the Lake region.

Charts of the second group, viz., those showing the duration of sunshine in percentages of the possible duration, have been prepared by the U. S. Weather Bureau, and, more recently, also by Gläser. In 1898 Prof. A. J. Henry published the first map of normal annual sunshine for the United States.[3]

The percentages of sunshine were obtained by subtracting the mean annual cloudiness from 100. A later table, published in 1906, gave, for varying periods of time, the percentages of sunshine derived from the records of automatically-recording instruments at a number of selected stations.[4] Sunshine recorders began to be installed at Weather Bureau stations in the early nineties, and now practically all stations are provided with these instruments.

A later map of normal annual sunshine, compiled from observations at Weather Bureau stations from 1871 to 1908, inclusive, was published as one of a series of climatic charts issued by the Weather Bureau. This map, also, seems to have been based upon the values obtained by subtracting the mean annual cloudiness from 100. In Gläser's monograph, above referred to, there are included charts showing the isohels for each month and for the year, the percentages being based upon instrumental records. These published charts of mean annual sunshine do not differ much from one another. The highest percentage of sunshine (over 80 per cent) is in the extreme southwestern interior. The minimum amounts (40 per cent) are found on the North Pacific coast, and over portions of the Lake Region and of the extreme northeast. Most of the country has not far from 50 per cent. The maps and tables published by the Weather Bureau, together with the monthly, seasonal and other mapsand diagrams prepared by Gläser, have thus brought together a large amount of information concerning sunshine in the United States.

* For instance with the sky "cloudy" with cirro-stratus bright sunshine may be recorded for hours.—ED.

[1] W. J. van Bebber: "Die Sonnenscheindauer in Europe und Nordamerika," *Natur und Offenbarung*, Vol. 42, Münster, 1896, pp. 705–716, with map. Reproduced in *Atlas of Meteorology*. Pl. 18; text, p. 17.

[2] Arthur Gläser: "Bewölkungsverhältnisse und Sonnenscheindauer von Nordamerika," *Archiv. der Deutschen Seewarte*, Vol. 35, 1912, No. 1, 4to pp. 66; pls. 7; figs. 22.

[3] Alfred J. Henry: "Normal Annual Sunshine and Snowfall," *Mo. Wea. Rev.*, Vol. 26, 1898, p. 108, with map (Chart X) and table giving the annual percentages of sunshine by calendar years for each of the regular Weather Bureau and Canadian stations.

[4] Alfred J. Henry: "Climatology of the United States," *Bulletin Q.* U. S. Weather Bureau, 4to. Washington, D. C., 1906. Table IX, p. 110; text p. 65.

The essential facts are these: The north has less sunshine than the south. The west has on the whole more sunshine than the east. The southwest is the sunniest; the northwest and northeast are the least sunny. East of the Rocky Mountains there is less difference between north and south than to the west of the continental divide. There is less contrast between north and south on the Atlantic than on the Pacific coast. The west coast has the advantage in regard to sunshine as far north as latitude 40° N.; from there northwards, the conditions are reversed. Winter is as a whole distinctly the least, and summer the most sunny season.

Many interesting comparisons suggest themselves as regards sunshine between Europe and the United States, but this consideration is not an appropriate part of the present bibliographic note. It may, however, be interesting to add that the contrast between western Europe and eastern North America was clearly emphasized by Woeikof a number of years ago.[5] He pointed out that the American coast has great advantages in respect to sunshine, especially if stations having similar temperatures and not stations in the same latitudes are considered. "Not only is the duration of sunshine longer (on the American coast) but the air is clearer, especially in the colder months. This contrast is very strikingly emphasized on the voyage from England to the United States."

A NEW INSTRUMENT FOR MEASURING SKY RADIATION.

By Dr. ANDERS ÅNGSTRÖM.

[Dated: Meteorological Bureau, Stockholm, Sweden, October, 1919.]

The idea of comparing the heat produced or lost at a certain surface by radiation with the heat produced through an electrical current in order to balance the named gain or loss of heat has shown itself most fruitful in the construction of instruments for cosmical radiation measurements. Thus after the electrical compensation pyrheliometer was constructed in 1893 by K. Ångström,[1] the same principle was used by him in 1905[2] in order to determine the so-called nocturnal radiation, and now recently by Abbot and Aldrich,[3] attempting to measure the intensity of the diffused daylight by an ingeniously modified type of the compensation pyrheliometer.

A fairly good idea having been obtained of solar radiation and its variations, the last-named problem is at present one of the most important in actinometry and certainly also in meteorology in general. At high latitudes the heat transferred to the surface of the earth through luminous radiation from the sky, viz, through diffused sun radiation, must, on the average, amount to about 40 per cent of the total heat income from sun and sky together, and in the artic regions this source of heat and light is during the winter time the most important one.

In the following, I will give a description of a new instrument for measuring luminous-sky radiation founded upon the method of electrical compensation. The instrument may be used also for measuring the radiation of the sun and it may easily, in proper combination, be used as a self-recording instrument.

The construction is schematically shown by figure 1 (A, B, and C). It is in its main features very similar to the construction of the nocturnal radiation actinometer (the pyrgeometer). The bright strips of the pyrgeometer are, however, here replaced by strips that first are blackened with platinum black and afterwards covered with magnesium oxide to proper thickness. *aa* and *bb* in figure 1 (A and C) show the white and black strips, respectively, mounted on a hard-rubber frame in the end of a nickel-plated tube. Thermo-electric junctions are provided at the back of the strips, but electrically insulated from them. These junctions may be connected

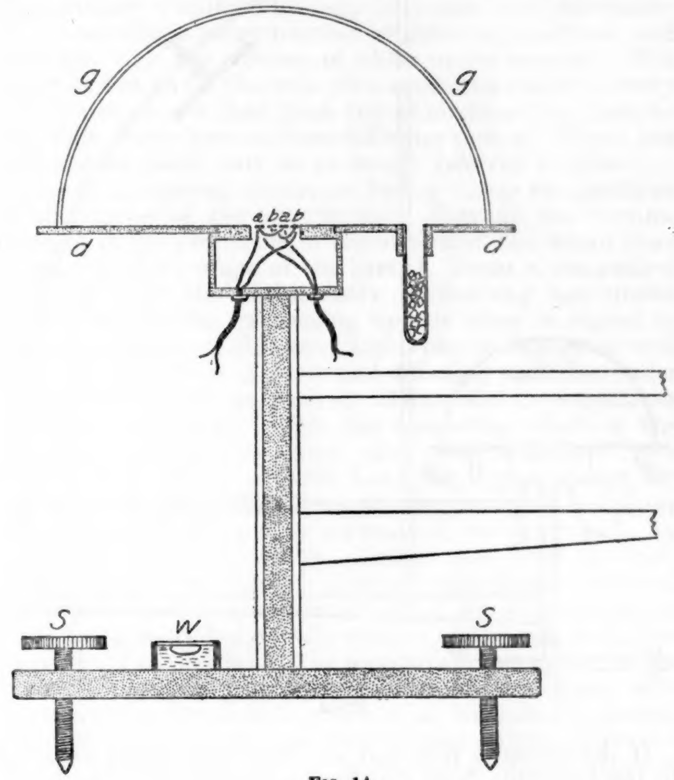


FIG. 1A.

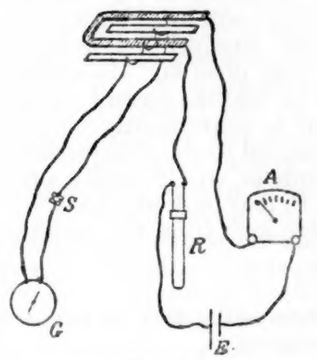


Fig. 1B

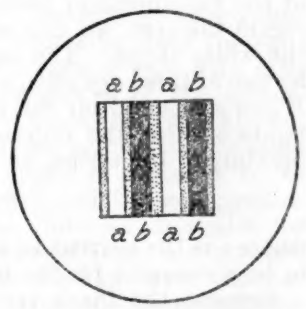


FIG. 1C.

in a circuit that also includes a delicate galvanometer G (fig. 1 B). To the tube and in the same plane with the strips is attached a circular metal disk *dd*, which acts as a support for the hemispherical glass screen *gg*, covering the strips, the purpose of which will be explained below. The metal disk is covered on its upper side by white paper, which is a better reflector for short wave radiation than the bright metal. On the supporting metal disk can also be placed a cylindrical metal cover in order to exclude the instrument from radiation from sun and sky. Through the water-level *w* and the two leveling screws *s* the hori-

[5] A. Woeikof: "Die Klimate der Erde" Jena, 1887, Part II, p. 45.
[1] K. Ångström: Nova Acta Upsal., 1893.
[2] K. Ångström: Nova Acta Upsal., 1905.
[3] Abbott and Aldrich: Smithsonian Misc. Coll., 66, Nos. 7 and 11.

zontal position of the strips can be controlled. By means of a simple device, whose construction is clear from figure 2, the sun may be screened off. The distance of the circular screen from the center of the strips is 40 cm., its diameter about 5 cm.

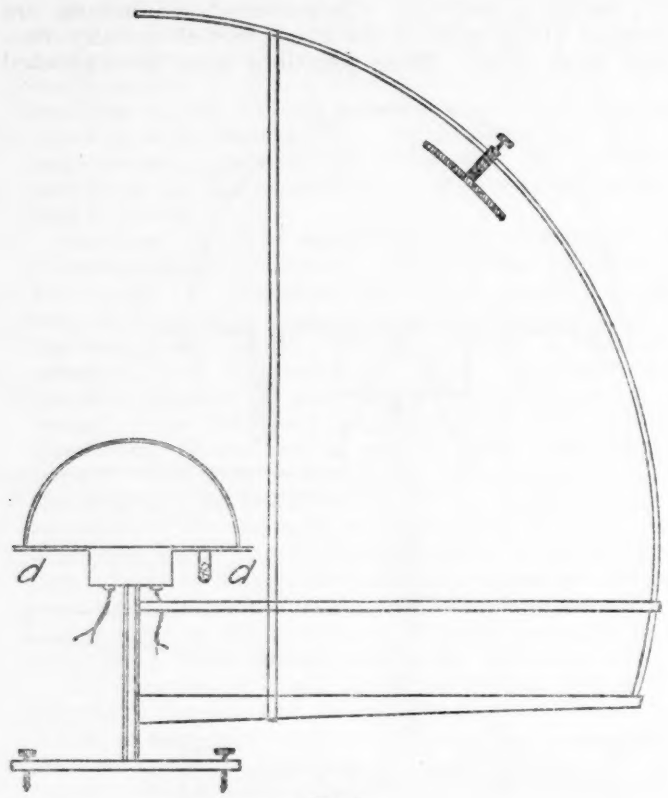


FIG. 2.

If the cover is removed and the instrument exposed to the radiation from the sun or the day sky, the black strips will absorb more heat than the white ones and consequently a temperature difference will arise between the thermo-junctions at their backs, producing a deflection of the galvanometer from its zero position. In order to regain the zero, we may send an electric current through the white strips. The current is conveniently obtained by two or three dry cells, is regulated by the slide resistance R and measured on the millameter A. We may investigate whether the radiation, R, may not, at equal temperature of the strips, be determined from the equation:

$$R = C. i^2 \qquad (1)$$

where i is the current in amperes and c may be expected to be a constant for the instrument.

Suppose the black strips to absorb the fraction α, the white strips to absorb the fraction β of the incident radiation. When the white strips are heated to the same temperature as the black strips we have:

$$\alpha R = \beta R + \frac{w i^2}{4.19}$$

which gives:

$$R = \frac{w}{4.19 (\alpha - \beta) i^2} \qquad (2)$$

The difficulty in the construction of instruments for measuring the intensity of a radiation made up of several different wave lengths, lies chiefly in the selection of surfaces whose effective absorption power remains constant when changes occur in the quality of the incident radiation. If the intensity of the radiation is the same in two cases, we wish the indications of the instrument to be the same also, independent of an eventual change in the relative intensity of the various wave lengths constituting the radiation. Strictly, this is only the case when the absorption of the surface is the same for all wave lengths constituting the radiation to be measured. Some experiments which will be described below indicate that practically both the platinum black (which is well known) and the magnesium oxide fulfill this condition in the case of the sky radiation.

When we intend to measure the luminous sky radiation separately, we must take precautions to exclude the heat radiation exchanged partly between the surface and the atmosphere and partly radiated by the surface directly out to space.

This radiation is of long wave length. Its maximum of intensity lies at about 10μ, but its intensity is negligible at wave lengths shorter than 3μ. On the other hand, the luminous sky radiation has its maximum of intensity at the blue end of the spectrum, its intensity being negligible for wave lengths longer than about 2μ.

I have tried to exclude the dark radiation from influencing the indications of the instrument in a twofold way. First it may be conceived from Coblentz's[4] measurements that the magnesium oxide, though having a high and almost constant power of diffuse reflection for the short and visible waves constituting the luminous sky radiation, has a very low reflecting power and consequently a high radiation and absorption power for waves longer than 4μ. The reflecting power at 8.8μ near where the effective heat radiation has its maximum, is in fact according to Coblentz[5] only 2.5 per cent and almost exactly the same as that of platinum black (about 2 per cent). The black and white strips radiate consequently almost equally for the dark waves, which implies that these waves do not influence the temperature equilibrium between the strips or the readings of the instrument. It then is to be expected that there ought not to be any appreciable deflection of the galvanometer, when the instrument is exposed without the glass cover to the nocturnal radiation. In fact, the deflection corresponding to a nocturnal radiation of about 0.18 gm. cal. cm². min. was found to be less than 5 mm. against 60 mm. for the same luminous radiation. In order to cut out entirely the long-wave radiation and at the same time protect the strips against air currents the strips are covered by the hemispherical glass cover referred to above, which lets pass freely the short waves but screens off the waves longer than about 3μ. No appreciable deflection could be detected when the glass-covered instrument was exposed to the nocturnal radiation. The heating or cooling of the glass is hereby of practically no consequence, while the strips are affected almost equally by the dark radiation. This property of equal absorbing power for dark rays gives the instrument a superiority over the Callendar instrument, in which the difference in temperature between bright and blackened metal surfaces is taken as a measure of the radiation, and also over the Abbot and Aldrich pyranometer, where the strips are equally affected by all waves. In both these instruments the heating or cooling of the glass cover must necessarily give rise to a superposed long-wave radiation liable to introduce errors in the result.

[4] Coblentz, W. W.: Bulletin of the Bureau of Standards, 9. 1913.
[5] Loc. cit.

DETERMINATION OF THE CONSTANT.

Experiments having shown that different instruments, constructed according to the idea explained above, read parallel to one another within 2 per cent, the radiation being computed from the formula:

$$R = c\, i^2 \qquad (1)$$

it remained highly desirable to determine the constant c in order that the readings may be directly transferred into gm. cal. per cm.^{2} per min., i. e., the usual actinometric unit.

A preliminary value of the constant c in (1) was obtained through a comparison between the sky actinometer and the Ångström pyrheliometer Nr. 158,[6] both being exposed to the sun radiation only. Comparisons on various occasions gave values ranging from 8.5 to 8.7, the mean value being 8.61. This value can, however, be considered only as a rough approximation when applied to the sky radiation measurements, since the qualities of the two radiations are different, the sun radiation being strong, the luminous sky radiation weak, in the infra red. It is consequently to be expected that the value of β in (2) will be slightly different for the sky radiation from what it is for the radiation from the sun. This difficulty which was overcome through comparing the indications of the sky actinometer with those of the pyrheliometer, when they both were exposed to a "filtered" sun radiation of approximately the same wave-length distribution as in the sky light. For a filter I used a combination of a blue glass (Schott & Genossen Nr. F 3086) and a water screen 1.5 cm. in thickness. The constant obtained in that way is 8.42, which is slightly lower than the preliminary value. This is to be expected since β has a higher value for the long-wave radiation partly entering in the sun radiation, than for the short waves.

A comparison between this instrument and the pyranometer of Abbot and Aldrich showed that the difference between the readings of the two instruments is less than 2 per cent. Individual readings differ, however, by as much as 6 per cent due, according to my opinion, to the fact that the pyranometer readings are influenced by the heating of the glass screen.

A comparison with the Callendar recording instrument used at the observatory of the U. S. Weather Bureau, under the direction of Professor Kimball, showed also a satisfactory agreement in the averages. The Callendar readings were, however, under conditions of very calm weather, undoubtedly influenced by the heating of the glass, the convection of the heat from the glass through the air being then small. The effect is generally not a large one, but may under special conditions amount to as much as 10 per cent.

The results of a number of measurements with the newly constructed instrument, with the object of determining the radiation from a clear sky for different heights of the sun and for different transmission powers of the atmosphere, as well of studying also the influence of clouds upon sky radiation, are under preparation and will probably soon be published. In the meantime, I take the opportunity to express my sincerest thanks to Director Marvin and the staff of the U. S. Weather Bureau for the facilities afforded me during my stay at the Bureau in July and August, 1919. Especially to Prof. H. H. Kimball I am indebted for his kind assistance in mounting and comparing the different instruments and for the facilities afforded me at his observatory in general.

[6] The constant of this instrument as determined at Upsala is 13, 58; the difference os its reading from the Smithsonian scale is 4,58 per cent. See "Notes on comparison between pyrheliometers, etc., this REVIEW, p. 798–799.

SOME PROBLEMS RELATING TO THE SCATTERED RADIATION FROM THE SKY.

By ANDERS ÅNGSTRÖM.

[Dated: Geographical Institute, Bergen, Norway, September, 1919.]

The knowledge of the optical phenomena exhibited by the sky has always been considered of high value for the local forecasting of weather. Thus a dark blue sky shows that there are few diffusing particles in the atmosphere and generally a low content of water vapor. On the contrary a milky-white sky indicates that the atmosphere contains a large number of diffusing particles and generally that the content of water vapor is great. The latter is apt to be the case also when the sunset is very red, which shows that then the atmosphere, at least in the west, must have a high diffusing power. These are well-known facts, only to be briefly referred to here.

One of the special questions falling under the problem of the optics of the sky, is this: How do the various changes in the properties of the sky affect the direct heat income to the surface of the earth? From a theoretical point of view the actinometry of the sky has shown itself most fruitful in clearing up our ideas in regard to the construction of different atmospheric layers as well as to the properties of gases and diffusing particles under the action of light in general. Thus, the investigations of Abbot and Fowle[1] upon the scattering effect of the cloudless atmosphere upon the sun radiation have shown, in combination with Lord Rayleigh's theory for scattering in gases, that the scattering of the atmosphere above about 3 kilometers altitude is caused mainly by the effect of the molecules. Below that level the dust atmosphere, increasing in density with depth, plays an important part in the weakening of the sun radiation. First the spectro-bolometric studies of the sun radiation have given us an idea of the amount of energy stored up through absorption in different atmospheric layers and have made it possible to explain, at least in its general features, the temperature distribution in the upper-air layers, and at first view its rather astonishing feature of the great inversion.[2]

We know the total heat radiated to a horizontal surface by sun and sky to be of prime importance in determining the temperature distribution in its relation to time as well as to coordinates. Several investigations have been carried out on the radiation from the sun; and its variation with zenith-distance of sun, with altitude, water vapor, and diffusing power of the atmosphere, may at present be said to be relatively well known, even if much is yet to be done before the relation between sun radiation and climate is revealed to us more in detail. Angot has computed the solar radiation on a horizontal surface at different latitudes for different transmission coefficients of the atmosphere, the transmission assumed to be constant over the surface of the earth. It is one of the objects of pyrheliometry to revise the latter assumption according to actual conditions. But the computation of Angot and his followers has not taken into consideration the important part played by the diffuse sky radiation, the observations of which are few and generally of accidental character. The observations show, however, that the radiation from the sky is relatively large, that for high sun, clear sky, and medium diffusing power it is about 20 per cent of the solar radiation, but that its percentage increases rapidly for increasing zenith distance of the

[1] Annals of the Astrophysical Observatory of Smithsonian Institution, Vol. III.

[2] *R. Emden:* Über Strahlungsgleichgewicht und atmosphärische Strahlung. (Sitz. ber. d. Bayerischen Akad. d. Wissenschaften München, 1913.)
W. J. Humphreys: Astrophys. Journal. Vol. XXIX.
E. Gold: Proc. Roy. Soc. of London, ser. A 1909.

sun and with increase in cloudiness. In the first place under the more simple conditions presented by a clear sky, one of the prime objects of sky actinometry ought to be to fix the relation between the radiation from the sky on the one hand and the height of the sun and diffusing power of the atmosphere on the other. Here a comparison between the observations and the theory of L. V. King may be of value, and may lead to a conception of the ratio between the amount of radiant energy diffused by the dust particles and the amount transformed by them into heat. A close agreement between observations and the theory named is not to be expected without an extension of the theory or an adjustment of the observations, while the reflection of the light from the earth's surface introduces a complication not considered in the theory. This is probably the reason why Aldrich,[1] observing in California, found a more rapid decrease in the sky radiation than demanded by the theory.

From the climatological point of view the influence of clouds upon the heat exchange is naturally of great importance, though very difficult to subject to general rules. The cloud-forms are innumerable and the influence of different clouds exhibits great variations. From my observations at Upsala, with the instrument described above in the summer of 1918, and at Washington in the summer of 1919, I have drawn up the following table, wherein the numbers ought only to be taken to be what they are—the average of some few cases.

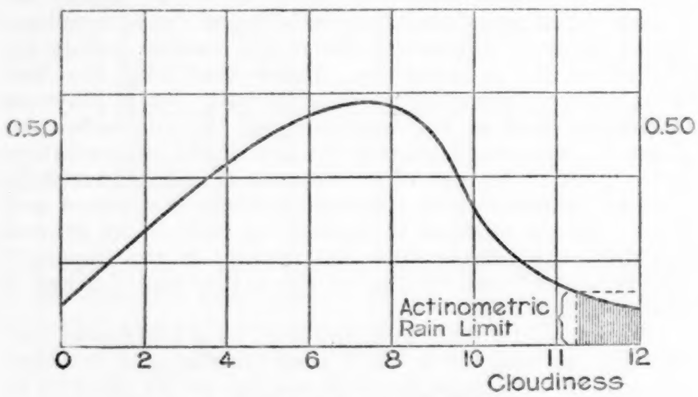


FIG. 1.—Variation in sky radiation with cloudiness.

TABLE 1.—*Variation in sky radiation with cloudiness.*

(Sun's zenith distance 10°–30°.)

	R. gr. cal. cm². min.	$\frac{dR}{dn}$
(1) Radiation from clear sky:		
(a) Transmission for sun radiation about 0.75	0.10	+
(b) Transmission for sun radiation about 0.50	0.30	+
(2) Sky covered by Ci-St	0.15–0.30	+
(3) Sky covered by A-St	0.20–0.40	+
(4) Sky covered by St-Cu (not very dense), about	0.50	±
(5) Sky covered by Nb (not very dense), about	0.35	−
(6) Sky covered by Nb (very dense)	0.10	−

The table shows some interesting and important features. With increasing density [n = nebulosity] of the cloud sheet the radiation from the sky first increases in order to reach a maximum, after which it decreases with increased heaviness of the cloud. For the cloudiness corresponding to the maximum of sky radiation, the sun radiation is practically nil. The radiation income corresponding to the cloudiness 10 is consequently under these conditions not equal to 0, as is often assumed, but about 50 per cent of the sun radiation when the sky is clear. On the average the cloudiness 10 causes a decrease in the total heat income down to about 30 per cent. In regard to the influence of cloudiness upon the total heat income, I have given a survey of the question, just published in the *Meteorologische Zeitschrift*,[3] on the basis of Kimball's observations with the Callendar recording-instrument. A more detailed treatment of the question will soon appear by Prof. Kimball himself.[4] The superposition of the diffused sky radiation upon the direct radiation from the sun is, in large part, the reason that the heat income at the cloudiness 5 (or 50 per cent) is nearly 80 per cent of the heat income for clear sky.

After the maximum is reached an increased cloudiness causes a decrease in the radiation from the sky. When the radiation from the sky has reached a certain low value—not very different from the value corresponding to a clear sky—rain generally begins to fall. This actinometric rain limit is naturally dependent upon the height of the sun above the horizon, but seems, for uniformly clouded sky and constant solar height, to maintain a value that fluctuates only between narrow limits. For the local forecasting of rain a closer investigation of these conditions may prove to be of value.

Purely physical and mathematical problems may be solved by one single investigator limited to a certain place and, in regard to time, dependent only upon the rapidity of the work of the investigator's brain or his experimental speed and skill. But meteorological problems need for their solution many observers distributed over wide areas and continuing their work over considerable intervals of time. If the present paper has been able to draw attention and attach interest to some of the wide problems offered by the actinometry of the sky, it will have filled its purpose.

NOTE ON COMPARISONS BETWEEN PYRHELIOMETERS AND ON THE DIFFERENCE BETWEEN THE ÅNGSTRÖM STANDARD AND THE SMITHSONIAN STANDARD.

By Dr. ANDERS ÅNGSTRÖM.

[Dated: Meteorological Bureau, Stockholm, Sweden, October, 1919.]

The constant of the Ångström pyrheliometer No. 158, used by myself during expeditions to Algeria and California, was determined in 1912 from measurements of the width and resistance of the strips and found to be 13.58.[1] Using this value of the constant, the instrument was found to read 1.25 per cent lower than the standard instrument of the solar observatory at Upsala $\left[\frac{\text{Å } 158}{\text{Å. S.}} = 0.9875\right]$, which we will indicate in the following by the Ångström Standard (Å. S.).[2] Shortly afterwards (in the summer 1912) the pyrheliometer No. 158 was compared by Dr. Abbot and myself with a newly standarized secondary pyrheliometer of the Smithsonian, (A. P. O. 9), and later by Dr. Abbot with the Smithsonian secondary standard itself (A. P. O. 8. bis.). The results of these comparisons were that No. 158 read 4.58 per cent ±0.15 lower than the Smithsonian standard (*S. I. S.*) $\left[\frac{\text{S. I. S.}}{\text{Å } 158} = 1.0458\right]$. Consequently the differ-

[1] Aldrich, L. B. The Smithsonian eclipse expedition of June 8, 1918 (Smithsonian Misc. coll., No. 9, 1919).

[1] At the Solar Observatory at Upsala by Dr. Lindholm.
[2] As A. S. the pyrheliometer No. 70 has since 1906 been in permanent use.
[3] Ångström, Anders: Met. Zschft. H. 9/10, 1919.
[4] Kimball, H. H. See this REVIEW, pp. 769–793.

ence between the Å. S. and the S. I. S., was in 1912 3.27 per cent $\left[\frac{\text{S. I. S.}}{\text{Å. S.}}=1.0327\right]$.

Six years later—in the summer of 1919—I have now had the opportunity to make a new comparison between the readings of the Ångström pyrheliometer No. 158 and the Smithsonian scale at the observatory of Prof. Kimball of the U. S. Weather Bureau. A number of simultaneous readings were taken with No. 158 and the newly standardized Smithsonian Silver disk pyrheliometer No. 1. The conditions of the sky were not very favorable, very thin cirro-stratus causing irregular disturbances. No. 158 was found to read 4.9 ± 0.4 per cent lower than the Smithsonian (August 1919) $\left[\frac{\text{S. I. S.}}{\text{Å 158}}=1.049\right]$.

Immediately after my return to Sweden, No. 158 was compared by Dr. Lundblad with the Å. S. During the time of the observations the conditions of the sky were very favorable, the atmosphere being clear, the air very pure and calm weather prevailing. No. 158 was found to read 1.60 per cent ($\pm$ 0.1) lower than the Å. S. $\left[\frac{\text{Å 158}}{\text{Å. S.}}=0.984\right]$. Consequently the difference between the Å. S. and the S. I. S. is at present (in October 1919) found to be 3.23 per cent $\left[\frac{\text{S. I. S.}}{\text{Å. S.}}=1.0323\right]$.

There is an excellent agreement between this value and the one obtained 6 years ago, the difference falling much below the probable error (about $\pm$ 0.2 per cent). The result agrees further very well with results of comparisons by Marten at Potsdam, who found the difference between the Å. S. and the S. I. S. to be on the average 3.4 per cent.[3] From my comparisons it may be regarded as a safe conclusion, that neither the Ångström Standard nor the Smithsonian Standard has since 1912 been subjected to changes which practically need to be considered. The previous discussion consequently supports as well the opinions expressed by G. Granquist[4] in regard to the Ångstrom standard as those of C. G. Abbot[5] in regard to the Smithsonian one.

In a previous paper I have given reasons for assuming that 1.8 per cent of the difference between the pyrheliometer scales may be due to special features in the construction of the compensation pyrheliometer, whose readings consequently in general ought to be corrected by + 1.8 per cent. The remaining 1.5 per cent I am still inclined to believe to adhere to the Smithsonian scale, the measurements of Coblentz and of Royds having supported the value found by K. Ångstrom for the absorption power of soot and applied by him to the computed values of pyrheliometer constants.[6]

In applying given constants to pyrheliometric readings, it is, as in the case of all instruments, of great importance to make sure that the instrument itself is in unchanged condition, at least in its general and perceivable features. No one expects accurate results from the readings of a thermometer whose bulb has been broken, or a barometer whose mercury has been oxidized. In using the electrical-compensation pyrheliometer it is important to make sure that the strips are straight, uniformly black, and adhering to the supporting frame. An important source of error may arise from the fact that the measurements involve the use of a millammeter for reading the compensation current. Generally these millammeters are good and their temperature coefficient negligible—at least my own experience with the millammeters of Siemens and Halske and of Weston Electrical Instrument Company has been highly satisfactory. But it sometimes occurs that instruments even of the best make will show considerable errors, especially with change in temperature, and a control is therefore necessary. Especially the ammeters, which on expeditions are carried along with a pyrheliometer, need control through comparisons with other instruments or through new standardization at certain intervals. These precautions taken, the electrical compensation pyrheliometers seem, according to my experience, to be constant in their readings. Their disadvantage compared with the Smithsonian secondaries lies in their more delicate construction and their need of auxiliary instruments. Their chief advantage lies in the possibility of controlling the constant determination by measuring the width and resistance of the strips, which ought to be possible at every well-furnished physical laboratory; and, further, in the possibility of giving almost momentary values of radiation, which is especially important when one attempts to measure, for instance, the transmission of clouds, or tries to follow rapid variations in the radiation.

To Dr. Abbot, Prof. Kimball, Dr. Lindholm and Dr. Lundblad, my thanks are due for assistance in comparisons.

[3] W. Marten: Messunger der Sownerstrahlung in Potsdam in der Jahrcu 1909 bis 1912. (Veröff. des Königl. Preuss. Meteor. Inst., No. 267).

[4] Bericht über die erste Tagung der Strahlungs Kommision des internationalen Meteor. Komitees in Rapperswyl bei Zürich in September, 1912, Anhang IV, 1912.

[5] *Abbot and Aldrich:* Smithsonian Misc. Coll. Bd. 60, 1913.

[6] W. W. Coblentz: Bull. of Bureau of Standards, *9*, 193. Royds: Phys. Zeitschrift 1910, p. 316.

COMPARISON OF METHODS FOR COMPUTING DAILY MEAN TEMPERATURES: EFFECT OF DISCREPANCIES UPON INVESTIGATIONS OF CLIMATOLOGISTS AND BIOLOGISTS.

By F. Z. HARTZELL, Associate Entomologist.

(Author's abstract of Technical Bulletin No. 68, N. Y. Agricultural Experiment Station, Geneva, N. Y., June, 1919, 8°, 35 pp., 19 figs.)

[Dated: Vineyard Laboratory, Agricultural Experiment Station, Fredonia, N. Y., Nov. 8, 1919.]

The daily mean temperature is the thermal time unit in most general use among climatologists and ecological workers in botany and zoology; and, usually, this average is computed from maximum and minimum readings taken at some convenient hour. The true daily mean temperature is secured by mechanically integrating, with a planimeter, the corrected thermograph curve of the drum type of thermograph, or, in any case, by summing the average hourly temperatures, and dividing the result by 24 in every case. This mean is designated the thermograph average, while the approximate mean, computed from maximum and minimum readings, is known by the hour at which the observations were recorded; viz, the midnight, 12 p. m., 8 p. m., or 5 p. m. average.

It was found that the thermograph average seldom was the same as any of the corresponding approximate averages. The differences have been designated "discrepancies"; which are positive if the given average is greater than the thermograph average; negative, if less. The discrepancies for the various averages at Fredonia, N. Y. (Lake Erie Valley), for every day of 1916, were investigated by means of the statistical methods of Pearson.

In order to analyze the data, so as to determine the effect of the discrepancies on the mean annual temperature, the discrepancies for each series of averages were combined in frequency polygons, and the theoretical

curves fitted to the observations. Owing to the extreme variations in the range of the several distributions it was necessary to use different units of grouping, which fact must be borne in mind in comparing the several polygons. Convenient intervals for grouping were found to be: For the 5 p. m. discrepancies, 2.0°; for the 8 p. m., 1.5°; for midnight, 0.8°. The several frequency polygons and their theoretical curves are shown in figures 1 to 3. The fitted curves are of Pearson's type IV.

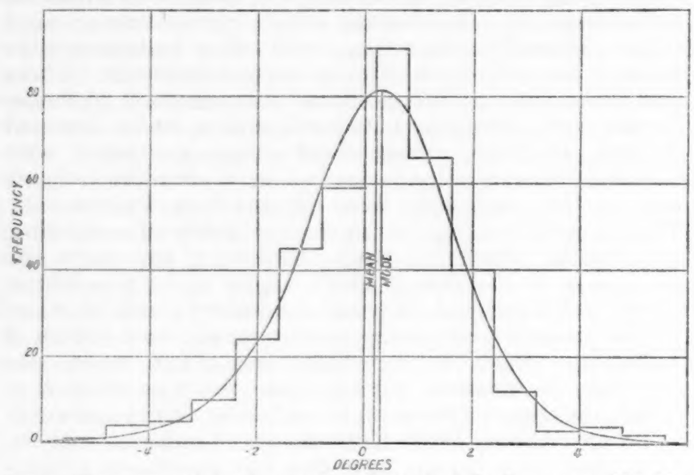


FIG. 1.—Histogram and fitted curve of variation in daily discrepancy. Midnight record. Fredonia, N. Y., 1916.

On the basis of a year's record, it was found that: (1) Small discrepancies occur more frequently than large ones; (2) within the limits of the times of observations used in this study, the time of observation determines the probability of large discrepancies, the 5 o'clock averages producing many more large values than observations made later in the day produced; (3) positive

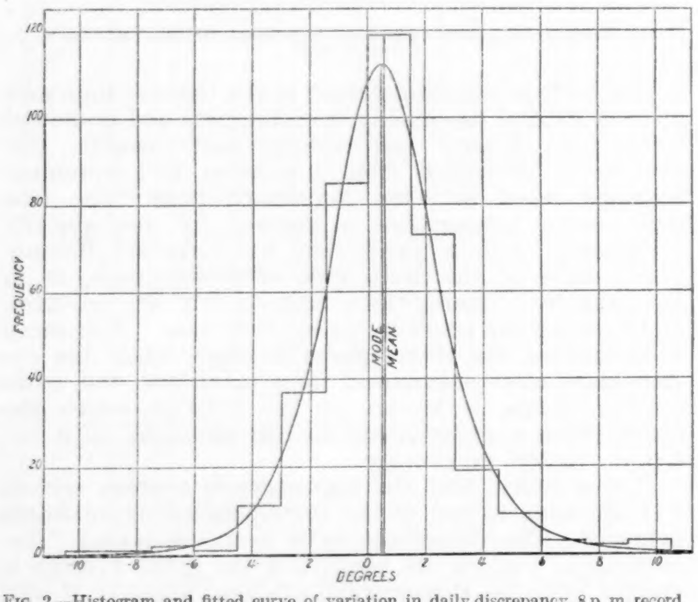


FIG. 2.—Histogram and fitted curve of variation in daily discrepancy, 8 p. m. record. Fredonia, N. Y., 1916.

discrepancies are of more frequent occurrence than negative ones, thus causing the approximate mean annual temperature to be too high; these differences are greater the earlier the hour of observation; (4) no method of using maximum and minimum temperatures is as exact as that based on the summation of hourly temperatures or as the integration of the thermograph curve.

The discrepancies in the annual mean temperature are: For the 5 p. m. observations, 1.21 ±0.11°; 8 p. m., 0.58 ±0.08°; midnight, 0.20 ±0.056°. Thus, from a practical viewpoint, averages of daily maximum and minimum temperatures, when the observations are made not earlier than 8 p. m., affect the annual mean temperature so slightly that the differences are negligible for all purposes, but averages for observations earlier than this hour introduce differences that may be important in some studies. A study of the standard deviations of the discrepancies supports these conclusions. Figures 1 to 3 show the ranges.

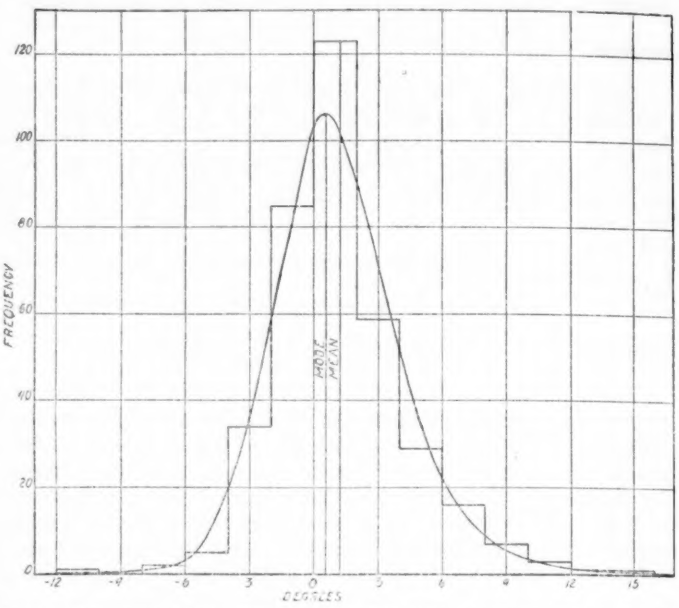


FIG. 3.—Histogram and fitted curve of variation in daily discrepancy, 5 p. m. record. Fredonia, N. Y., 1916.

The greatest discrepancies occurred on the days of the winter months, and the smallest during the summer months. July showed the smallest deviations. This is because the disturbances superposed upon the normal diurnal temperature curve are most pronounced and irregular during the winter. The discrepancies introduced into the mean monthly temperatures by the several series of observations are shown in figure 4. For

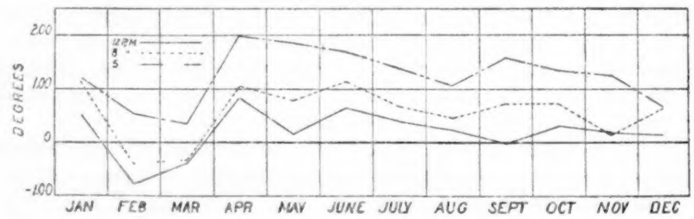


FIG. 4.—Graph showing the variation in average monthly discrepancies during 1916. Fredonia, N. Y.

meteorological purposes, these were perhaps not excessive when the hour of observation was not earlier than 8 p. m., but, for biological purposes, it is advisable to use thermograph averages.

The differences in the mean daily temperature between successive days of the month were calculated for each series of observations, and it was found that on many days the divergencies were excessive in every record. The only mean that can be depended upon for the investigation of either climatology or biology, when daily differences are to be compared, is that given by

the thermograph average. Owing to the extreme variation in the discrepancies from day to day, the use of the shorter method of computing means may introduce errors which will mask relationships between thermal influence and biological activity.

Perhaps the chief result of this study is the proof of the fact that *if approximate averages are employed, the same hour of observation should be used if the data are expected to be comparable.* The taking of readings before 8 o'clock in the evening is not to be recommended for *any* purpose, owing to the extreme differences that will be introduced in the averages.

When daily means are used in the summation of effective temperatures, or of temperature co-efficients, for the study of thermal influence in botany and zoology, thermograph averages alone should be used, since approximate means introduce rather large errors, especially during the spring months, as is shown in Table 1.

The U. S. Weather Bureau practice being to average the temperature extremes from midnight to midnight, the normals so computed are adequate for meteorological purposes. In the case of cooperative observers, who have no thermograph record by which to do this, records taken at 8 o'clock in the evening appear to be the most desirable if maximum and minimum thermometers are in use, since the errors of computation introduced are not excessive, and the hour is convenient for the observer. When the variation of the exposure of the instruments is considered, it is doubtful whether any important gain in the accuracy in the mean temperature for a month would be secured by furnishing cooperative observers with thermographs. Such are essential for biological purposes, however.

TABLE 1.—*Summation of daily mean temperatures above 39° F., Fredonia, N. Y., 1916.*

(From Apr. 11 to the end of the month indicated.)

Record.	April.		May.		June.		July.		August.	
	Summation.	Per cent discrepancy.	Summation.	Per cent discrepancy.	Summation.	Per cent discrepancy.	Summation.	Per cent discrepancy.	Summation.	Per cent discrepancy.
	°F.		°F.		°F.		°F.		°F.	
Thermograph	151.7	0	654.9	0	1,337	0	2,474	0	3,505	0
Midnight	164.5	8.4	672.5	2.7	1,374	2.7	2,523	1.9	3,561	1.6
8 p. m	166.5	9.8	694.0	6.0	1,410	5.5	2,568	3.8	3,613	3.1
5 p. m	183.5	20.9	744.5	13.7	1,477	10.5	2,657	7.4	3,721	6.1

PARADE-GROUND TEMPERATURES AT COLLEGE STATION, TEX.

By CHARLES F. BROOKS.

In June, 1918, at College Station, Tex., some observations were made of parade-ground temperatures under different conditions of cloudiness, and were also compared with temperatures in the grass and air. The instrument was a physical thermometer upon which the boiling point was about 101.5° C., and the freezing point at 0.2° C. The temperatures mentioned below are uncorrected for instrumental error. The influence on the dust temperature of the passage of the shadow of a cumulus cloud is shown in the following table:

About sunrise the next morning it was found that the temperature in the dust was about 27.8° C., in the air about 1 meter above the ground, 25.9° C., and in the grass 24.7° C. In the afternoon, with the thermometer placed under 2 or 3 mm. of dust, a temperature of 61.3 C°. (142° F.) was obtained; in the grass 48.6° C. (120° F.); in the air about 38° C. (101° F.). In this case it is noted that the breeze seemed to make little difference with the temperatures of the dust. The maximum temperature was obtained when the thermometer was placed in a dust hole slope normal to the sun's rays. A temperature of 61.7° C., or about 143° F., was obtained.

TABLE 1.—*June 18, 1918.*

Time (p.m.).	Thermometer.	Remarks.
	°C.	
3:08	59.5	Exposed in gray dust at depth of ½ cm. for 5 minutes Sun had been shining for some time.
3:09	53.1	Beginning of cumulus shadow.
3:17	53.1	In cloud shadow. Sky cover 0.6 St.Cu., 0.2 Ci.St.
3:20	51.9	Still in shadow.
3:21	51.6	Do.
3:22	51.3	Do.
3:22:30	51.1	Sun reappearing.
3:23:30	52.4	Strong sunlight.
3:24:30	53.6	Do.
3:25:30	54.7	Do.
3:27:30	45.3	Under green grass, about 1 cm. from top of grass, and so placed that direct sunlight did not strike bulb. In poor air circulation. Strong sunlight.
3:28	43.8	Same exposure.
3:29	42.8	Do.
3:29:30	42.2	Light clouds.
3:30	41.7	Do.
3:31	40.8	Very light clouds.
3:32	40.5	Beginning of thick cloud. Gusty east wind.
3:45	38.5	Air temperature on roof of three-story building in thermometer shelter.

HIGH RELATIVE TEMPERATURES OF PAVEMENT SURFACES.

By G. S. EATON.

[Abstracted from the Engineering News-Record, Mar. 27, 1919, p. 633.]

Maximum temperatures, relatively high with respect to adjacent locations, were found by engineers of the Universal Portland Cement Co., on asphalt, brick, and concrete surfaces. From 11 a. m. to 6:30 p. m. the average readings for the three types of surfaces in the order named were 118°, 113°, and 108°. This is of special interest with respect to the effect of these high temperatures on rubber tires, horses' hoofs, and shoe leather. It is known that a large part of the tire trouble experienced by motorists is due to expansion of the air due to heat. High pavement temperatures would doubtless play a large part in aggravating this condition.

"During the middle of the day the effect of the pavements in heating the air above them was noticeable, as thermometers 1 foot and 4 feet above the roadways read from 3½ to 4½° higher than over a lawn in the sun. Temperatures above the pavements were found to be much the same, however, regardless of the type of surface. Over the asphalt, the readings averaged 1° higher than above the concrete and one-half degree higher than above the brick. After 7:30 p. m. the temperatures above the surfaces were practically the same as those of the surrounding air. The presence of large lawns and shade trees probably hastened the cooling and somewhat different results might be ex-

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pected in the closely built-up sections of a city. Temperatures in the shade, 30 feet away, were not influenced by the pavements."

These tests were made in Riverside, Ill., far enough inland to escape the lake breeze and all the pavements were in the same vicinity. Weather conditions were ideal, as the sky was clear, and the air temperatures recorded at Chicago were the highest of the summer.

"For each pavement, readings were taken at the surface, 1 foot and 4 feet above, and 30 feet to one side of the roadway in the shade of a lawn. An additional set of readings was taken 4 feet over grass in the sun. Thirteen standard 25 cm. Fahrenheit thermometers were used, each protected from direct sunlight by a white paper or pasteboard cover. Readings were taken every half hour from 8 a. m. to 10 p. m."

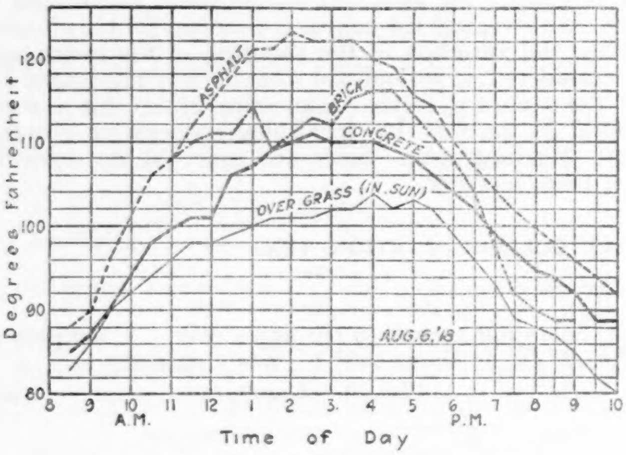


FIG. 1.—Surface temperatures for various types of surfacing.

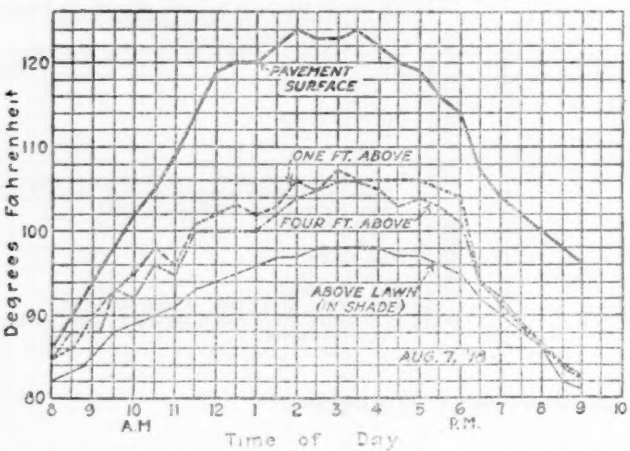


FIG. 2.—Variation between asphalt surfaces and various adjacent locations.

Figures 1 and 2 show sets of readings plotted between temperatures as ordinates and time of day as abcissae. "Figure 1 shows the difference between the various pavement surface temperatures and also the readings over a lawn in the sun. The drop in the brick temperature curve at 1:30 p. m. was due to the moving of the observation station on account of the encroachment of shade. No point could be found on the brick surface that was in the sun for the entire day. The rapid drop in the same curve between 6 and 8 p. m. was probably due to the proximity of the Des Plaines River, as air temperatures taken near showed a similar drop. Figure 2 shows the relation, for an asphalt pavement, between temperatures at the surface, 1 foot above, 4 feet above, and in the shade 30 feet to one side of the roadway."—*C. L. M.*

COMPARISON OF ROAD-SUBGRADE AND AIR TEMPERATURES.

By C. C. WILEY.

[Abstracted from Engineering News-Record, July 17, 1919, pp. 128-129.]

"Investigations were started at the University of Illinois in the belief that some of the phenomena of cracking and heaving of brick and concrete roads can be explained by a study of the range and rate of change in temperatures within the pavement and in the underlying soil. The observations will extend over a considerable period of time to obtain data concerning some of these factors." Preliminary records show that changes in temperature are transferred very slowly from the air to the subsoil, and that the subgrade extremes lag considerably behind those of the air.

"The fact that the changes of temperature at the bottom of the slab are considerably slower and much less in magnitude than those of the air may be worth considering in connection with protecting a new pavement from freezing. Also it may be noted that the change from maximum to minimum temperatures in the slab takes place over a considerable length of time, during which the slab and subgrade have an opportunity to adjust themselves to the changed conditions."—*C. L. M.*

PENETRATION OF PERIODIC TEMPERATURE WAVES INTO THE SOIL.

By K. AICHI.

[Reprinted from Science Abstracts, Sect., A, Mar. 31, 1919, § 240.]

The paper deals in a theoretical manner with the conduction of heat through a substance such as the soil. In working out the annual temperature wave at depths of 1 m., 2 m., and so on from that at the surface it is customary to assume the conductivity and specific heat constant throughout each layer. This is far from being the case, and it is shown that the assumption invalidates the results of such calculations. The ratio of the conductivity to the specific heat can be obtained (1) from the change of amplitude of the temperature wave with depth, and (2) from the retardation of phase, and in certain practical examples to which the formulæ are applied in the customary manner it is found that the results from (1) and (2) are in very poor agreement. In the paper certain cases where the conductivity varies with depth in a specified manner are treated mathematically.—*J. S. Di.*

NEW METHOD OF REDUCTION OF OBSERVATIONS OF UNDERGROUND TEMPERATURE.

By K. AICHI.

[Abstract reprinted from Science Abstracts, Apr. 30, 1919, p. 151. Art. in Phys.-Math. Soc., Japan, Proc. 1 (Ser. 3) pp. 2-7. Jan., 1919.]

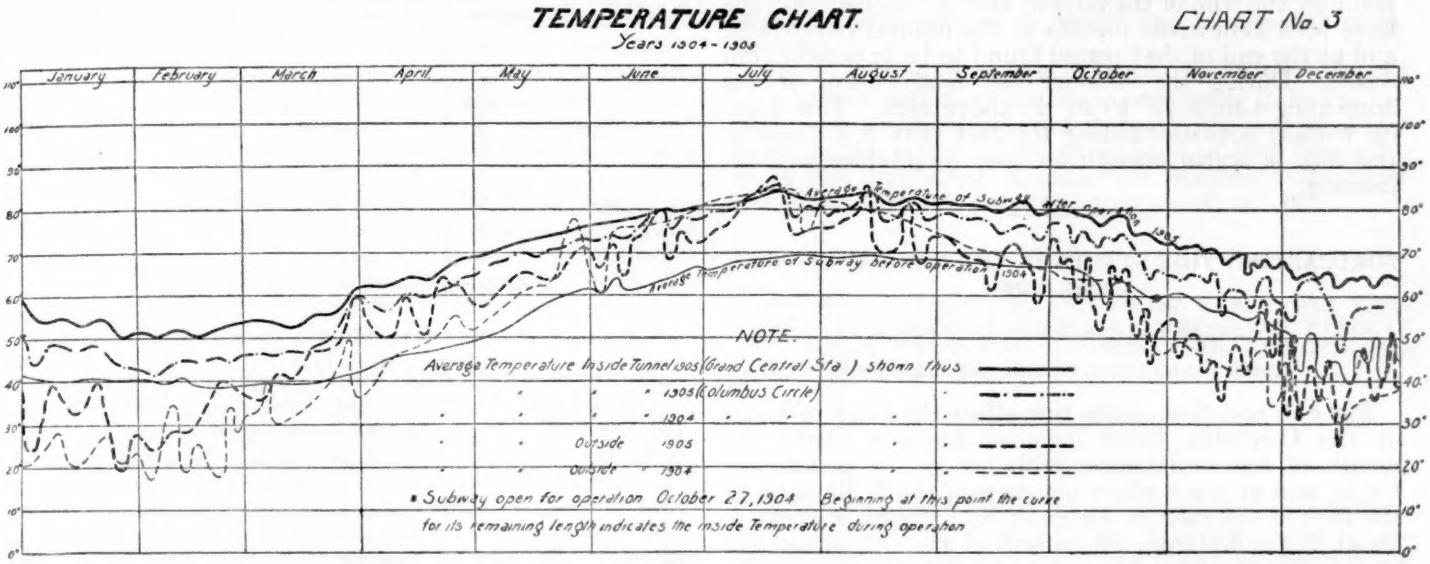
A further discussion concerning the passage of the annual temperature wave downward through the soil, where the conductivity K and specific heat C vary with depth, see Abs. 240, 1919. If temperature observations were available at all depths, K and C could be calculated uniquely as functions of the depth, but actually, where observations at certain specified depths only are taken, a definite solution of the problem is not possible. Various methods of calculating the "equivalent diffusivity" of the layer between two points of observation are discussed and numerical examples are worked out.—*J. S. Di.*

TEMPERATURES IN NEW YORK SUBWAYS.

Through the courtesy of Mr. D. L. Turner, Chief Engineer, Transit Construction Commissioner, State of New York, thirteen prints were obtained showing the temperatures in New York subways, 1904–1917. The most interesting two are reproduced as figures 1 and 2.

Figure 1 shows strikingly the effect of operation on the temperature, the temperatures during operation averaging 11° to 20° F. higher than those before operation. Can this be due to the combined effect of human and mechanical heat? Before operation the average temperature, about 54° F. nearly coincides, as would be expected, with the mean annual air temperature of New York, 52° F. The range of the average temperature, 39° to 69° F., is only two-thirds the range of mean monthly air temperature at New York City.

Figure 2 attests to the efficient ventilation of the subways. Cold days outside are cold days in the subways and warm days are warm outside and in. The temperature variability, is, necessarily, less than half as great in the subways as outside.—*C. F. B.*



F G. 1.– This chart is designed to show, in a general way, the relative variations in temperatnre inside and outside of tunnel for the years 1904 and 1905, with the particular object of showing the changes inside the tunnel resulting from the operation of trains. The thermometer at Columbus Circle is at the south end of west platform, while that at Grand Central Station is about 70 feet west of south-bound-train platform, between south-bound local and express tracks, and gives the approximate average temperature throughout the subway at stations and intermediate points.

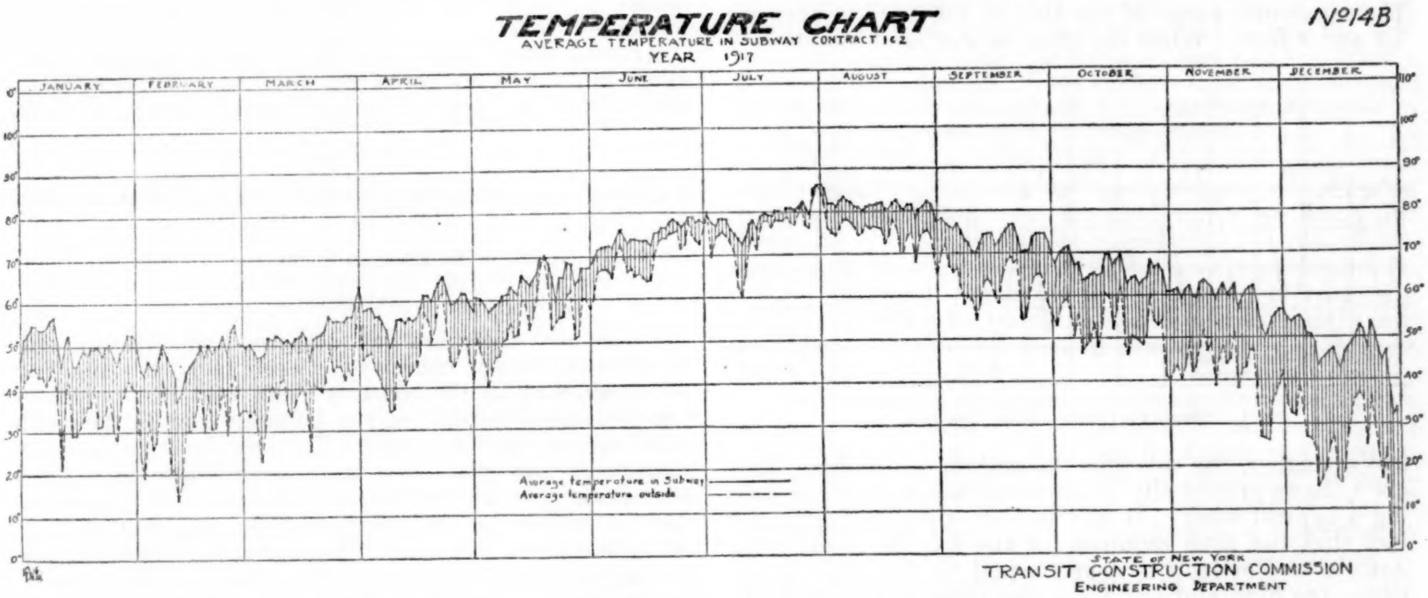


Fig. 2.—Average 1917 daily air temperatures outside and in the Manhattan-Bronx & Brooklyn subways covered by contracts 1 and 2.

AN ICE MINE THAT FREEZES IN SUMMER AND MELTS IN WINTER.

By C. A. Vandermuelen.

[Reprinted from Sci. Am., May 6, 1916, pp. 470 and 495.]

Note.—The following account draws attention to a striking effect of the slowness with which the annual temperature wave goes into the ground.—Ed.

"It was discovered some 18 years ago by a farmer who, noting a peculiar coldness—even in the warmest weather—of a certain portion of his farm, was led to dig there in the belief that he would find a deposit of silver. [Near Coudersport, Pa.] The mine or cave which he unearthed proved to be 40 feet deep and from 10 to 12 feet in diameter. At present it is entered by

means of a ladder, since it is situated on the side of hill. * * * The ice is formed from a peculiar cold mist which comes through openings found all the way from the top to the bottom of the 40-foot shaft. As soon as the warm weather arrives frost appears on the walls of the shaft and soon tiny icicles form rapidly, until in the warmest weather huge icicles, often 2 feet thick, reach from the platform at the top, to the bottom of the mine. The ice begins forming in May, and in October the thaw sets in. A shelter was erected over the mine some time ago; but it had to be removed because the ice melted. * * * The mine has been used as a cold storage plant by the wife of the farmer, and she claims that eggs have been kept seven months in the natural refrigerator and at the end of that period found to be in perfect condition. During the summer the temperature of the mine ranges from 25° to 30° F. above zero. This mine, [in winter] notwithstanding the fact that it is open at the top, is warm enough to keep vegetables without freezing."

FORECASTING TIDE STAGES IN THE HARBOR AT PORTLAND, OREG.

EDWARD LANSING WELLS, Meteorologist.

[Dated: Weather Bureau, Portland, Oreg., Oct. 16, 1919.]

The ebb and flow of the tide affect the stage of water in the Columbia River for some distance above the mouth of the Willamette, probably as far as Cascade Locks, and at times affect the stage of the Willamette to the foot of the falls at Oregon City. Cascade Locks is about 150 miles from the mouth of the Columbia, and Oregon City is about 120 miles.

The zero of the river gage at Portland is less than 1 foot above mean sea level. The maximum range of the tide at Astoria, 99 miles below Portland, is about 12 feet. The maximum range of the tide at Portland is between 3.5 and 4 feet. When the river at Portland stands at 9 feet or higher, the tide effect is seldom noticeable. Figure 1 shows graphically the rise and fall of the river during a typical week. It will be seen that, owing to the fact that the time required for the tide to travel from Astoria to Portland is nearly equal to the interval between the high and low tides, the actual water level at Astoria is occasionally higher than at Portland. This condition is apparently never sufficiently pronounced to cause a reversal or even a cessation of the current in the Columbia, but at low-water stages there is a noticeable reversal of the current in the lower reaches of the Willamette.

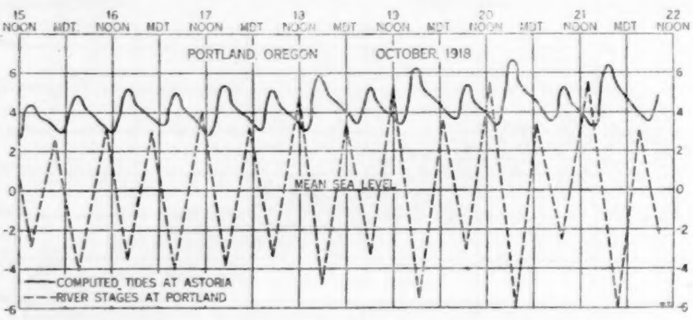


FIG. 1.—Tides in the Columbia River, Oct. 15-22, 1918.

During settled weather, when the normal stage of water in the Columbia and Willamette is low, as during the late summer and early fall of 1918 and 1919, it has been found that high tide at Portland occurs about 6 hours later than at Astoria, and that the maximum stage at Portland, based on the zero of the river gauge, will be about 45 per cent to 55 per cent of the computed stage at Astoria, based on mean lower low water, which is the datum used in current tide tables. Figure 2 shows the relation for the month of October, 1918.

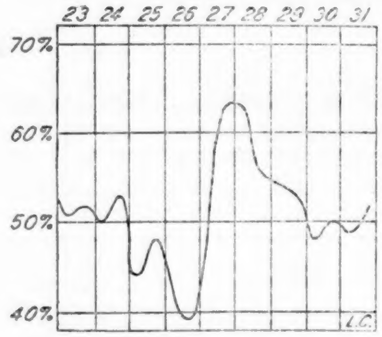


FIG. 2.—Relation of tide at Portland to computed tide at Astoria, Oct. 23-31, 1918.

However, when high winds occur along or near the coast, the actual stages at Astoria vary considerably from the computed tides, and at such times accurate predictions for Portland can not be made. Weather maps of October 25-27, indicate an increasing pressure gradient that favored on-shore gales attending the extreme variation that occurred on October 26 and 27, as indicated in figure 2. It appears that as the storm approaches, the offshore winds hold the water back; later, as the storm advances, the winds change, piling the water up. This heaping up of the water is doubtless due more to the action of winds well out to sea than to winds along the immediate coast.

Arrangements were made to install a recording tide gauge at Astoria, for use in this connection, but conditions arising after the close of the war made this impracticable

BAROMETRIC PRESSURE, WINDS, AND STORMS OF THE PACIFIC OCEAN.[1]

By EDWARD A. BEALS.

[Abstract.]

In January there are two areas of high pressure centered, respectively, midway between Honolulu and San Francisco and off the coast of Chile, and three areas of low pressure centered over the Aleutian Islands, the south polar regions, and Australia. In July the Aleutian LOW disappears and there is a HIGH over Australia. These formations are subject to seasonal variations in position and magnitude, because of the shifting apparent position of the sun in the heavens. They are caused by the familiar inequality of the heating of the land and water areas, and by dynamical causes inherent in the planetary circulation.

The usual system of spirally flowing winds surrounds these formations. The proximity of the North Pacific HIGH to the American coast is the cause of the rainless

[1] Presented at the Pasadena meeting of the A. A. A. S., June, 1919. Published in full by University of California Press, 1920.

summers in California, Oregon, and Washington, as it brings air from the colder portion of the ocean in over the land, which, as soon as it is reached, increases the temperature of the air, and thereby its capacity for retaining water vapor in an invisible state. The dryness of the land adjacent to the South Pacific HIGH is even greater than in the Northern Hemisphere, for the southern HIGH is less subject to changes from summer to winter than the northern one.

The tropical regions of the Pacific are under the influence of the trades, which show seasonal variations, and the monsoons.

This general system of air circulation is frequently invaded by storms, both tropical and extratropical, of which the Pacific has its full quota. But little is known, however, of the storms of either kind which occur in the Southern Hemisphere. The storms of the Northern Hemisphere are strongly influenced by the semi-permanent "centers of action," e. g., the Aleutian LOW and the North Pacific HIGH.

There is a great need for additional information as to the centers of action of the Pacific and the changes taking place in them; this information could be obtained by the establishment of more first-class meteorological stations on the islands and coasts of the Pacific; by maintaining cruisers equipped for meteorological observations, including aerological observations, at permanent stations or within limited areas; and by enlisting every Pacific ship for the purpose of taking observations, including those of the temperature and salinity of the water. Progress along all of these lines has already commenced.—*E. W. W.*

THE DISTRIBUTION OF TEMPERATURES AND SALINITIES, AND THE CIRCULATION, IN THE NORTH PACIFIC OCEAN.[1]

By GEORGE F. MCEWEN.

[Abstract.]

Observation shows that, by reason of well-known causes, no part of the ocean is motionless. Observations of temperature and salinity are of great value in determining the details of the oceanic circulation, for the presence of water differing significantly in any property from that corresponding to local conditions indicates a flow of water from regions where different conditions prevail. The vertical and horizontal flow of water is the factor most concerned in modifying the simple temperature distribution to be expected from the variation of solar radiation with respect to latitude and from the distribution of land and water. The thermal equator is at latitude 10° N.; most of the surface of the Atlantic from latitudes 20° to 60° N. is from 1° to 4° above the normal temperature at corresponding latitudes, and the North Pacific averages 2° colder than the North Atlantic; greater temperature anomalies are found in many small areas. The distribution of salinity is even more irregular, depending upon more factors. In both the northern oceans the maximum surface salinity is found in the Horse latitudes, but it is notably higher in the Atlantic. In some regions, e. g., the Bahamas, the salinity decreases continually from the surface to the bottom, while in others, e. g., the North Pacific off southern California, it decreases only in the upper 40 meters, and increases from there to the bottom.

A great desideratum is a systematic study of the North Pacific comparable with [or even more extensive than] that which has been made of the North Atlantic. Observations now available, though inadequate, supply the following general information:

Owing to the well-known difference in the heating effects of insolation upon land and upon water, the water of the North Pacific, from the Equator to 45°, tends to be colder than land, especially in summer, and that north of 45°, especially in winter, tends to be warmer than land; these tendencies in part give rise, respectively, to the HIGH about 1,500 miles west of San Francisco, and to the Aleutian LOW. The resulting winds cause the North Pacific oceanic circulation to be, in its main outlines, a clockwise eddy lying between the Equator and latitude 45°. Great modifications as to details and to seasonal variations exist.

The California current is shown to be an upwelling of cold bottom water, which the author holds to be continuous with a slow northward drift of cold bottom water from the Antarctic. (For an account of how this influences the California climate, see McEwen, MONTHLY WEATHER REVIEW, 1914, **42**, 14-23.).—*E. W. W.*

[1] Presented at the Pasadena meeting of the A. A. A. S., June, 1919. Published in full by University of California Press, 1920.

A PHYSICAL THEORY OF OCEAN OR RESERVOIR TEMPERATURE DISTRIBUTIONS REGARDED AS EFFECTS OF SOLAR RADIATION, EVAPORATION, AND THE RESULTING CONVECTION.[1]

By GEO. F. MCEWEN.

[Author's abstract.]

Assume radiant energy to be absorbed in accordance with the well-known exponential function of the thickness of the medium traversed, and that a similar relation having a larger exponent holds for the removal of heat by evaporation, since the direct effect of the latter is confined to a comparatively thin surface layer, in spite of the mechanical disturbance usually present near the surface. It then follows that evaporation removes heat at a greater rate near the surface than can be directly supplied by radiation. This surface layer thus becomes colder than that underneath, and consequently tends to change places with it. This interchange may not be complete. That is, a fraction r of the cold upper layer may remain to mix with the fraction $(1-r)$ of the rising warmer layer. Similarly, the cold water replacing this warm layer tends to change places with the one underneath, and so on downward. Thus a convective circulation is generated consisting of the descent of relatively cold water elements, and the ascent of relatively warm ones in which the difference in temperature decreases as the depth increases

Two differential equations, one giving the rate of change of the temperature of the descending cold water, the other giving the temperature rate for the ascending warm water can be derived from these assumptions. Regarding the measured temperature as the mean of that of the intermixed warm and cold elements, a combination of the two differential equations into a single one can be obtained whose solution, subject to suitable boundary conditions gives the relation in such form as to admit of observational tests. The satisfactory qualitative agreement of one such solution with generally accepted facts led to preliminary estimates of the physical constants. The results thus found appear to justify an extended investigation of the theory.

[1] Presented before American Physical Society, St. Louis, December 30, 1919.

DETECTING OCEAN CURRENTS BY OBSERVING THEIR HYDROGEN-ION CONCENTRATION.

By ALFRED GOLDSBOROUGH MAYOR.

[Abstracted from Proceedings of the American Philosophical Society, Vol. 58, No. 2 pp. 150-160, 1919.]

The hydrogen-ion concentration of pure distilled water is about 10^{-7} grams per liter at 22° C. Sea water is alkaline, containing only about one-tenth this amount. The surface water of the equatorial drift of the Pacific contains a hydrogen-ion concentration of about 0.6021×0^{-8}; occasionally, however, there are found regions of water which is temporarily flowing eastward, and this is less alkaline, the concentration being sometimes as high as 0.83×10^{-8}. The easterly flowing water is also cooler, has a high oxygen content, and is strongly charged with CO_2 where as the tension of the CO_2 in the westward drift is about the same as that of the air above the sea. These easterly currents are due to upwelling of bottom water, due to local causes, such as the removal of the surface water by gusts in the trade winds.

The hydrogen-ion concentration is dependent chiefly upon the temperature, and not upon the salinity, of the water.

Similar studies support McEwen's theory of the upwelling of water along the abrupt slope of the Pacific coast of America, and Bigelow's demonstration of the same, but less marked, effect, off the shallow Atlantic seaboard.

In general, if no upwelling is taking place, the CO_2 of the sea water is always practically in balance with that in the air over the water; this balance is, in warm waters, brought about by the influence of photosynthesis by marine plants, and the escape of large quantities of CO_2 from the sea into the air is prevented, contrary to the opinions based upon the laboratory experiments of Henderson and Cohn. The colder surface waters of the globe are absorbing carbon dioxide, while the tropical regions are probably setting some of it free into the atmosphere, but on the whole a balance is probably maintained.

The detection of the sudden and marked change from alkaline water to relatively acid water when one encounters an easterly set in the tropical Pacific, or passes from a warm into a cold current, can be so easily made by means of the indicator thymolsulphonephthalein that this method may prove of value in navigation.

References to literature are given at the end of the paper.—*E. W. W.*

NOTES, ABSTRACTS AND REVIEWS.

ADDITIONAL NOTE ON THE INTERNATIONAL GEODETIC AND GEOPHYSICAL UNION.*

By Dr. L. A. BAUER.

The present convention is to continue for 12 years, beginning January 1, 1920, subject to renewal and modification at the end of this period. The general meetings are to take place every three years, when there will be opportunity for changes in organization or statutes as future experience may suggest. It will not be necessary for a Union to meet at the same place as the Council, or for all the various Unions to meet together. A section may, furthermore, call a special meeting when found necessary.

Objects of the International Geodetic and Geophysical Union.

The objects are stated in the official version, as follows:

1. To promote the study of problems concerned with the figure and physics of the earth.
2. To initiate and coordinate researches which depend upon international cooperation and to provide for their scientific discussion and publication.
3. To facilitate special researches such as the comparison of instruments used in different countries.

Section *c* (Meteorology), it was generally agreed, could usefully and effectively supplement, by confining its work to research and fundamental problems in meteorology, the functions and work of the prewar International Meteorological Committee. The latter, as it consisted of official weather bureau directors, necessarily had to concern itself, primarily, with administrative and official meteorological questions. In the unavoidable absence of the elected president, Sir Napier Shaw, no organization work was attempted except the passing of the two resolutions, to the following effect:

The hope is expressed—

(*a*) That there be appointed a Joint Committee of the International Astronomical Union and of the Section of Meteorology of the International Geodetic and Geophysical Union for investigational work on solar radiation;

(*b*) That international work in atmospheric electricity, as far as possible, be placed under the direction of a committee nominated partly by the Section of Terrestrial Magnetism and Electricity and partly by the Section of Meteorology.

With the organization of the Division of Foreign Relations of the National Research Council in Washington December 10 a means has been provided for active and well coordinated American effort in the international research organization.—ED.

* Complete notice is published in Terr. Mag. and Atmos. Elec., Sept. 1919, vol. 24, p. 105-112, and in Science, Oct. 31, 1919, p. 399-403. For previous notice see this REVIEW, July, 1919, pp. 449-450.

GOLD MEDAL TO PROF. HILDEBRANDSSON.

The Council of the Royal Meteorological Society has awarded the Symons memorial gold medal for 1920 to Prof. H. H. Hildebrandsson for distinguished work in connection with meteorological science.—Nature, London, November 27, 1919, page 340.

ATMOSPHERIC POLLUTION.[1]

[Abstract, reprinted from Science, New York, Nov. 28, 1919, p. 501.]

The advisory committee on atmospheric pollution has published its fourth report summing up the observations in the year 1917-18.

The full lists showing in detail the monthly deposit figures at various stations are not reproduced, inasmuch as these have been already published in the *Lancet;* but full returns from two stations, Newcastle and Malvern, are given; and these give the highest and lowest deposits.

Figures of total solids deposited monthly are given for all stations, 24 in number, the months being on a 30-day basis.

In many instances the rainfall as measured at these stations did not agree with the amount obtained by the official Meteorological Office gauges, but this is easily explained when it is remembered that the gauges of the committee are often on roofs and are thus elevated. The rainfall is given in millimeters, and it would be well if we in the United States would follow this example.

[1] Meteorological Office. Report on observations 1917-18. Advisory Committee on tamospheric pollution, London, 1919.

At a given London station the data for the half year, October to March, 1917–18, were:

Rainfall, 43 mm.; tar, 0.14 metric ton per square kilometer; carbonaceous matter other than tar, 2.18 tons; insoluble ash, 3.50; soluble ash, 4.15; or total solids, 11.41 tons. Of the soluble matter there were 1.46 tons of sulphate, 0.63 tons of chlorine, and 0.05 of ammonia.

No relationship can be discovered between the deposit of insoluble matter and the amount of rainfall. With the soluble matter, however, it is different, and in general it may be said to vary directly as the rainfall. The relation may be roughly expressed by the formula, $S = 0.058R + 2.5$, where R is the rainfall in mm. and S the deposit of soluble matter in tons per square kilometer. It is not suggested that this expression can be used to find the soluble deposit when the rainfall is known, but gives only the general nature of the relationship.

The report also contains the results of analysis of the rainfall at Georgetown, British Guiana, the nearest land in the direction of the prevailing east-northeast trade winds being the shore of Morocco, distant 3,000 nautical miles. There can be little doubt that the solids contained in the rain waters collected are those normal to the rains of the trade winds, with perhaps some derived from the coastal sea-spray.

The average results over the two years 1916 and 1917 were as follows:

	Solids in solution mg./liter.
Ca	7.95
Mg	3.44
K	2.77
Na	16.36
Al_2O_3	0.58
Fe_2O_3	1.97
SiO_2	0.20
Cl_2	33.93
SO_4	12.02
CO_3	9.78
NO_3	11.57
NH_4	0.12
	100.69

It is shown that 55 per cent of the solids in solution in the rainfall are cyclic sea salts, while 45 per cent must have been derived from atmospheric sources.

The report also contains an account of certain experiments made to determine the best method of measuring continuously the suspended impurity in the air.—*A. M.*

STUDY OF AEROLOGY IN THE AIR SERVICES.

[Reprinted from Aviation, New York, Nov. 15, 1919, p. 354.]

The Aerological School maintained at the Navy Air Station, Pensacola, Fla., will have an accession of 15 enlisted men to start the four months' prescribed course opening on December 1. Six of the students come from the Navy Air Service, three from the Marine Corps and six from the Army Air Service. The class of six with which the school opened is receiving training in aerology preliminary to taking the advanced course which will be maintained at the Weather Bureau in Washington, D. C.

AN INTERESTING OBSERVATION OF ATMOSPHERIC OZONE.

By HENRY I. BALDWIN.

[Dated: Saranac Lake, N. Y., Dec. 1, 1919.]

An interesting observation of ozone in nature was made by the writer on the summit of Haystack Mount (altitude 4918 feet), near Mount Marcy in the Adirondacks at 9:30 a. m., September 8, 1919. The wind at the time was from the west-southwest, having a velocity of approximately 35 miles per hour. The air temperature was probably about 60° F., although no instruments were available for taking observations. Wisps of fracto-stratus cloud were being blown across the rocky peak while 600 feet above were irregular masses of strato-cumulus. In these rapidly moving fragments of fracto-stratus clouds a very strong, pungent odor was perceptible, similar to that noticed near static machines and dynamos. Three hours earlier, that morning, several silent discharges had been seen in the clouds above the mountain, and then, at 3 p. m., a violent thunderstorm broke over the surrounding country.

The writer was at first inclined to believe the odor due to ozone liberated by electricity generated from friction of the clouds with the mountain. One author was found mentioning this as a cause of atmospheric ozone, but Prof. Humphreys's explanation is much more logical:

"There is no reason to expect the atmosphere to become electrified as a result of friction as it blows over mountain peaks, except, perhaps, when it is filled with heavy dust—when it is likely to be already considerably electrified."

"It often happens, however, that mountain peaks give off a great deal of silently discharged electricity, and this discharge may, at times and places, be sufficiently abundant to produce enough ozone and oxides of nitrogen (often mistaken for ozone), to be distinctly perceptible."

Since there was a negligible amount of dust present in this case, the ozone was formed in all probability by some form of electrical discharge which had taken place, or was taking place in the clouds. The effect may have been rendered more noticeable by moisture.

NITROGEN AND OTHER COMPOUNDS IN RAIN AND SNOW.

By J. E. TRIESCHMANN.

[Reprinted from Science Abstracts, Sect. A, Sept. 30, 1919, §1161.]

The paper summarises the results of an analysis of the impurities brought down in rain and snow at Mt. Vernon, Iowa, over a period of eight and one-half months. The town is small and without manufactories, so that there is no excessive local contamination. The precipitation (22¼ inches) supplied during the period 512 pounds of chlorine, 1.5 pounds of sulphates, and 5.3 pounds of nitrates per acre. The presence of the chlorine has been ascribed to salt particles carried from the Atlantic. The average part per million for free ammonia was 0.407; albuminoid ammonia, 0.366; nitrates, 0.255; and nitrites, 0.018. Rain was found to be richer in nitrogen contents than snow. [See also Abs. 146 (1919) to be reprinted in the next issue of the REVIEW.]—*J. S. Di[nes]*.

SIMPLE FORM OF APPARATUS FOR ESTIMATING THE OXYGEN CONTENT OF AIR FROM THE UPPER ATMOSPHERE.

By F. W. ASTON.

[Reprinted from Science Abstracts, Sect. A, Aug. 30, 1919, §1001.]

In the apparatus described a sample of about 10 cm. of air is drawn into a burette and by adjustment of a mercury column is compressed or expanded slightly so as to occupy a standard volume. The height of the mercury column is marked and the air then withdrawn and deoxidised by means of heated phosphorus. It is again

drawn into the measuring apparatus and made to occupy a volume which is equal to 79 per cent of that previously occupied by it. The difference of pressure from the former value is noted. As normal air contains 21 per cent oxygen the second pressure will be approximately equal to the first, and it is the difference between the two which indicates the departure of the oxygen content of the sample from that of normal air. 3 mm. pressure-difference on the mercury column corresponds with 1 per cent difference in oxygen content and readings can be obtained to 1/20th of a mm., or 1/60th of 1 per cent. The results of a test on a known sample of air (20.42 per cent of oxygen) are given. The value obtained by the use of the apparatus was 20.39 per cent.—*J. S. Di[nes]*.

A METHOD OF MEASURING VISIBILITY.

By A. WIGAND.

[Reprinted from Science Abstracts, Sect., A, Aug. 30, 1919, §1000.]

An instrument is described consisting of seven circular transparent glasses, mounted around a rotating disc attached to a frame, which can be fitted over the observer's eye in such a way that the glasses can be brought successively across the field of view while the eye is sheltered from stray side-light. The glasses vary regularly in opacity and are numbered 2, 4, 6, 8, 10, 12, and 14 respectively corresponding to the degree of opacity on an arbitrary but fixed scale. A rotating arm mounted on the axis of the disk carries another transparent glass of which the opacity is 1 on the same scale, so that an observer can interpose an opacity corresponding with any whole number from 1 to 15 between his eye and an object. Definite objects having been selected at various known distances from the observer, the method of observation is to select that transparent glass through which an object can just be seen, and to name as corresponding opacity given by the instrument the number of the glass next higher on the scale, through which the object is invisible. Experiment has shown that on a day of max. visibility the mean opacity number of the instrument is 14.3. If a is the opacity number on any occasion, $14.3-a$ is a measure of the lack of transparency of the atmosphere for the particular object seen, and $(14.3-a)/l$, where l is the distance of the object, is a measure of the lack of transparency of the air for unit distance of the object. The reciprocal of this, namely, $l/(14.3-a)$ is defined as the visibility (*Sicht*) of the air. Certain precautions required for making an observation, a list of causes of deterioration of visibility, and a number of actual observations are also given, together with a diagram which serves for the rapid evaluation of the above quantity for different values of a and l.—*R. C.*

LIGHTNING FIGURES.

In Symons's Meteorological Magazine for December, 1919, is a note by James G. Wood correcting the statement made by Dr. Newell in a note in the October number of the same magazine (abstracted in Monthly Weather Review, October, 1919, p. 729) relative to "impressions of branches and leaves" on the human body due to lightning strokes. Such markings are not uncommon and are due to the "ramification of an electric discharge."—*C. L. M.*

THE TOTAL SOLAR ECLIPSE OF MAY 29, 1919, AT CAPE PALMAS, LIBERIA.[1]

By Dr. LOUIS A. BAUER.

(Author's abstract.)

[Dated: Washington, D. C., Dec. 6, 1919.]

The station at Cape Palmas, Liberia, (lat. 4° 22′ N., long. 7° 43.7′ W.) was one of five principal stations at which magnetic and allied observations were carried out by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington in connection with the solar eclipse of May 29, 1919. Two of these stations, Sobral, Brazil, in charge of Mr. D. M. Wise, assisted by Mr. A. Thomson, and Cape Palmas, Liberia, in the author's charge, who was assisted by Mr. H. F. Johnston, were inside the belt of totality. A third station, at Huayao, Peru, north of the totality belt, was in charge of Dr. H. M. W. Edmonds; the fourth station south of the belt of totality, at Puerto Deseado, Argentina, was in charge of Mr. A. Sterling; and the fifth, about 100 miles north of the belt of totality, at Campo, Cameroun, was in charge of Mr. Frederick Brown. Observations were also made at a secondary station, Washington, by Mr. C. R. Duvall.

In addition to these stations, special magnetic observations were made at the Department's magnetic observatory at Watheroo, Western Australia, and at observatories all over the globe, both inside and outside of the region of visibility of the eclipse. Reports have already been received from many of these foreign observatories. The reports indicate that the magnetic conditions were ideal for the detection of a possible magnetic effect of the order to be expected from our previous eclipse magnetic observations. As soon as the various observations have been examined and discussed, a paper will be presented before the Society upon the results obtained.

The prime object of the present paper is to give a general account of our expedition to Cape Palmas, Liberia, also to relate the phenomena observed during the total eclipse, and the experiences encountered en route to Liberia and in Liberia itself.

Totality lasted at Cape Palmas about 6 minutes and 33 seconds, longer than at any other accessible station in the belt of totality. The general indications, as the eclipse occurred during the rainy season, were that Cape Palmas would not be a suitable station for the astronomer. However, for the purpose of our investigations, it did not matter whether we had a clear sky or not, for a magnetic effect will pass through any layer of clouds. It happened, however, that in spite of general expectation, we had clear weather, and this now for the third time, whereas parties at other stations which appeared more favorable according to past meteorological records, were unfortunate. Our observation program included magnetic and electric observations, meteorological observations, shadow band observations, times of contacts and photographs such as could be obtained with our small Kodak cameras. This comprehensive program was carried out successfully, excepting the atmospheric-electric work which, owing to the deterioration of the dry-cell batteries purchased in England, had to be abandoned. Although I had stationed three observers, no shadow bands were observed this time, even greater

[1] Presented before the Philosophical Society of Washington, Oct. 11, 1919.

precautions having been taken than at Corona, Colo., during the eclipse of June 8, 1918, where they were observed.

The eclipse of May 29 as observed at Cape Palmas, was not nearly as dark, in spite of its long duration, as the much shorter one of June 8, 1918, at Corona. There was a marked difference in light, both as seen visually and as shown by the photographs, between the inner corona and the outer extension. The large red prominence was a startling object.

Clear indications were had with regard to a magnetic effect in accordance with the results obtained at previous solar eclipses.

There was a steady slight decrease in temperature from 12^h G.M.T., 0.7 minute after the first contact, to 12.7^h G.M.T., and then a more rapid decrease until 14^h G.M.T., when the minimum temperature of 79.4° F was reached. This time (14^h) was approximately 0.4^h later than the middle time of totality. The increase in temperature after 14^h was rapid, the maximum 82.7° F being reached at 14.9^h G.M.T. The hygrogram for May 29 showed the following effect: The humidity, which was 71 per cent at 12^h G.M.T. steadily increased to 78 per cent at 14^h G.M.T. There was a more rapid decrease from 14^h G.M.T. to 15^h G.M.T., when the humidity was 66 per cent. The maximum humidity, therefore, occurred at 14^h, or approximately 0.4 hour later than the middle time of totality. The barogram showed nothing marked during the time of the eclipse.

VELOCITY OF THE WIND IN HIGH ALTITUDES IN CLEAR WEATHER.

By CH. MAURAIN.

[Abstracted from Comptes Rendus, July 15, 1919, pp. 79-82.]

In order to determine the average speed of the wind in extreme altitudes, as many records of sounding balloons as possible were assembled, and of these all those were taken which attained altitudes greater than 10 kilometers. From 198 such flights it was found that the mean speed of the wind increased in an almost linear manner from 5 meters per second at an altitude of 500 meters, to 15.6 meters per second at 11,000 meters, after which it began to decrease until it reached in the neighborhood of 8 meters per second at 19,000 meters. Of these flights, there were 11 in which a speed greater than 40 meters per second was observed, 2 in which it exceeded 50 meters per second, and one which gave a value of 55 meters per second. The last was observed at Pavie.—*C. L. M.*

THE MONSOONS OF TUNIS.

By J. ROUCH.

[Abstracted from Annales de Geographie, vol. 28, No. 153, pp. 226-229, 1919.]

The monsoon, the most important effect of the unequal heating of the continents and the oceans, is, except in a very few regions of the world, masked by the general circulation. The presence of this effect can, however, be clearly demonstrated by a method due to Allard and Angot:

The mean wind observed in any season is considered as resolvable into two components—the mean annual wind and a seasonal (monsoon) wind. From the triangle of velocities it is evident that the seasonal wind (monsoon component) is given by the diagonal of the parallelogram constructed on the mean annual wind and the mean wind observed in the given season.

Upon constructing the seasonal (monsoon) components by this method, and expressing each in terms of the mean annual wind, for six selected stations in Tunis, it is found that there is a strong winter monsoon component normal to the coast line, and directed toward the sea, for all coast stations, and that there is an equal monsoon component, oppositely directed, in summer.

At the inland stations, however, the effect is scarcely noticeable. At 200 kilometers from the coast the seasonal (monsoon) components are practically nil. Since isobaric charts show that the relative distribution of pressure over the eastern Mediterranean and southern Tunis is reversed between the two seasons, this fact can not be explained if it is assumed that the differences of pressure are alone responsible for the winds. Probably the temperature gradient, which is steep near the coast, must also be considered.

It is known that at some altitude the direction of the monsoon wind should be opposite to that of the surface. The aerological observations at Bizerte and at Sousse, Tunis, are expected to furnish information as to this altitude variation.—*E. W. W.*

ATMOSPHERIC WATER.

By OSCAR E. MEINZER.

[Abstracted from "Outline and Glossary of Ground-water Hydrology," an unpublished U. S. Geol. Surv. manuscript, pp. 1-7.]

The term "water" is used in geophysics to denote hydrogen monoxide, or chemically pure water, together with the solid, liquid, and gaseous materials held by the hydrogen monoxide as it exists in the earth in its natural condition."

The water of the earth may be divided into three parts—(1) Atmospheric water, the solid, liquid, and gaseous water which exists in the atmosphere; (2) surface water, the solid, and liquid water which exists on the upper surface of the lithosphere, i. e., in the hydrosphere; (3) subsurface water, the solid, liquid, and gaseous water which exists below the surface of the lithosphere. Water is often discharged from the atmosphere into the lithosphere, and vice versa, but, the capacities of these being limited, the hydrosphere becomes the receptacle for all water which the other "spheres" do not hold. Furthermore, the water-holding capacity of the atmosphere space alone changes rapidly and greatly, and the different parts of the atmosphere alternately receive water from, and yield water to, the hydrosphere and the lithosphere. The frequent changes in the water capacity of the atmospheric space are the principal cause of the continuous movement of water in the hydrosphere and lithosphere, and the principal agency that prevents the attainment of static equilibrium in the water of the earth.

Atmospheric water in the gaseous state is known as atmospheric water vapor. The solid and liquid water of the hydrosphere and lithosphere, and also any solid and liquid water which may exist in the atmosphere, are the sources of atmospheric water vapor, the process of conversion being known as evaporation, or vaporization. The term "evaporation" is also used to designate the quantity of water that is evaporated. When thus used it is generally expressed as depth of liquid water removed from a specified surface, most commonly in inches or centimeters. The rate of evaporation is expressed in units of depth per unit of time. The evap-

orativity or the potential rate of evaporation of a given part of the atmosphere is the rate of evaporation under the existing atmospheric conditions from a surface of water which is chemically pure and has the temperature of the atmosphere. It is expressed in depth of water (measured in liquid water) removed from the surface in a unit of time. Observations that give continuous records of evaporativity, some of them covering several years, are made at various localities by the U. S. Weather Bureau and by other agencies, by means of special apparatus and methods. The evaporation opportunity* afforded by a land surface or a surface of the hydrosphere in contact with the atmosphere is the ratio of the actual rate of evaporation from that surface to the evaporativity under existing atmospheric conditions. This ratio is generally stated as a percentage, and may be calculated by the formula

$$\textit{Relative evaporation} = 100\frac{e}{E}$$

where e is the actual rate of evaporation, in any convenient units, and E is the evaporativity in the same units. Generally, surfaces other than pure water surfaces have evaporation opportunities of less than 100 per cent, but under exceptional conditions of luxuriant vegetation the evaporation opportunity [relative evaporation] may be more than 100 per cent. The condition of any given part of the atmosphere with respect to its content of water vapor is known as the humidity.[1]

Solid and liquid water in the atmosphere may be derived mechanically from the hydrosphere, as through the action of wind in the cases of spray, drifting snow, etc., but it is largely derived through the process of condensation from the already existing atmospheric water vapor. Through the subsequent event of precipitation, atmospheric water becomes surface and subsurface water. Precipitation may be due to the falling of solid or liquid particles which have become too heavy to remain in suspension, or it may be due to the condensation, at the surface, of the earth of atmospheric water vapor, as in the cases of dew and frost. We thus have the following:

Classification of atmospheric water.

A. Water in gaseous state (Atmospheric water vapor); derived by evaporation.

B. Water in liquid or solid state:

1. Derived mechanically through the agency of wind: Spray, drifting snow, etc.
2. Derived by condensation:
   a. In small particles * * *. 1. At some distance above the surface of the land or the hydrosphere: [Some cloud [S]. 2. At or near the surface of the land or the hydrosphere: Fog.
   b. In larger particles * * *. Rain, snow, hail, sleet.—*E. W. W.*

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*"Relative evaporation" would be, perhaps, more expressive of what this term means, and it would be more or less analogous to relative humidity. The fact that relative evaporation is already in use to express the relative losses from evaporation pans of different sizes exposed in the same atmospheric environment, should not necessarily preclude such a new application of this term. We do not speak of the 'relative rainfall' when comparing the catches of adjacent rain-gages, but refer to differences in catch. In the same way, the instrumental differences in the indications of adjacent evaporimeters should be referred to as differences in water loss, or, perhaps, to retain the present designation, *relative evaporation loss*.—*C. F. B.*

[1] A *space* is said to be saturated with water vapor, if the quantity of water vapor it contains is the maximum which it can hold at the existing temperature; in the absence of dust particles or other nuclei which promote condensation, a state of supersaturation may exist, however. It is to be emphasized that *the capacity of a given part of the atmosphere for water vapor is nearly the same as that of a like empty space, being modified only slightly by the presence of the other constituents of the air.* (Author's footnote.)

SOME EXAMPLES OF THE "COMPRESSION OF A CYCLONE."

By G. GUILBERT.

[Reprinted from Science Abstracts, Sect. A, Aug. 30, 1919, §998.]

The author gives concrete cases of the application of one of his general rules for weather forecasting which is as follows: Every depression which is surrounded on all sides by "convergent" winds of which the velocities are abnormal by excess, will fill up *in situ* within 24 hours—sometimes within 12 hours—with high pressure in the middle of the former depression.—*R. C.*

ON THE ERRORS WHICH CAN RESULT FROM AN INCOMPLETE KNOWLEDGE OF AEROLOGICAL CONDITIONS.

By L. DUNOYER.

[Reprinted from Science Abstracts, Sect. A, Sept. 30, 1919, §1158.]

On a long flight such as that across the Atlantic variations of wind may produce considerable deviations from the intended course unless they are correctly allowed for. To obtain numerical results two cases are considered: (1) That of a cross wind of constant direction the strength of which follows a sine-curve variation, the breadth of the current from one place of zero velocity to the next; or half period, being equal to the length of the flight; and (2) the case where the velocity remains constant but the direction of the wind varies uniformly along the course. For each of these cases the deviation, or lateral error, in making the point aimed at is calculated on the assumption that (*a*) no allowance is made for drift, and (*b*) that allowance is made throughout for a constant wind equal to that prevailing at the start. Taking a speed of flight of 150 km./hour and a maximum wind velocity of 25 m./sec. the deviation at the end of the course may attain to four-tenths of the length of the route if no correction for wind is made (case *a*) or to eight-tenths if the starting wind is corrected for throughout (case *b*). The errors may thus be very important.—*J. S. Di[nes]*.

ATMOSPHERIC CONDITIONS WHICH AFFECT HEALTH.

By L. HILL.

[Reprinted from Science Abstracts, Sect. A, Sept. 30, 1919, §1159.]

The discomfort felt in crowded rooms is due to the low cooling and evaporating power of the air, not to its chemical impurities. To measure the cooling power from surfaces at body temperature the Kata-thermometer has been devised. The instrument is here described and the equations connecting its readings with the different meteorological elements (temperature, wind velocity, humidity, etc.) are set out. In an appendix the mean meteorological conditions are given for different stations and the cooling power is calculated. The cooling power in Madras in the shade and fully exposed to the wind during the worst months is found to be the same as that met with in shut-up rooms and factories in this country. Diagrams are given to prove how different the cooling power as shown by the Kata may be under different circumstances where ordinary thermometeric readings show little difference. The hope is expressed that cooling power at body temperature may be measured as part of the regular procedure at meteorological stations. It is also hoped that vapor pressure rather than, or in addition to, relative humidity may be recorded, as being of more service for determining the cooling of damp surfaces at body temperature.—*J. S. Di[nes]*.

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Sur la possibilité pour un avion de survoler les grains et les orages. [Paris] Bureau central météorologique. 1917. 4 [1] mimeographed sheets. 31 cm.

Sur le calcul du poids du mètre cube d'air aux diverses hauteurs à l'aide des observations faites au voisinage du sol. [Paris] Bureau central météorologique. 1917. 23 mimeographed sheets. table. 31½ cm.

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Water powers of British Columbia, including a review of water power legislation relating thereto and a discussion of various matters respecting the utilization and conservation of inland waters. By Arthur V. White, assisted by Charles J. Vick. Ottawa. 1919. ix [1] 644 p. plates. fold. map. charts. tables. 25½ cm. Two fold. maps in pocket at back. Bibliography, p. [602]–620. [Includes collected data and normals of precipitation and temperature for stations in British Columbia].

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Beobachtungen über die Beziehungen zwischen der Intensität der chemischen Strahlung und der Luftbewegung. Wien. 1919. cover-title. 39 p. charts. tables. 24½ cm. (Aus den Sitzungsberichten der Akademie der Wissenschaften in Wien. 1916. Mathem.-naturw. Klasse. Abt. 1. Band 128. Heft 2–3. 1919.)

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C. F. TALMAN, Professor in Charge of Library.

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SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING NOVEMBER, 1919.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Solar Radiation Investigations Section, Washington, Jan. 2, 1920.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1919, **47**: 4.

The monthly means and departures from normal in Table 1 show that radiation measurements averaged very close to November normal values at Washington and Lincoln, and slightly above normal at Madison. Unfortunately, the records for Santa Fe, N. Mex., were lost in the mails.

Table 3 shows only slight departures from the normal radiation for November at Madison and Lincoln, and a deficiency of 5 per cent at Washington.

The skylight polarization measurements made at Washington on 8 days give a mean of 53 per cent, with a maximum of 67 per cent on the 6th. At Madison, measurements made on 5 days give a mean of 70 per cent, with a maximum of 73 per cent on the 1st. The monthly mean at Washington is below, and that at Madison is above, the November average for the respective stations. The monthly maxima are average maxima for November.

TABLE 1.—*Solar radiation intensities during November, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Nov. 3						0.72		0.64	0.60	
5			1.24	1.15	1.06	0.96	0.87	0.79	0.71	0.65
6		1.35	1.31	1.24	1.16	1.07	1.00	0.96	0.92	0.87
14			1.25	1 13	1.03	0 94	0.86	0.78	0.71	
15					0.86	0.81	0.75	0.68		
17			1.06	0.91						
18			1.23	1.07	0.98	0.91				
20			1.13	1.01	0.91	0.82	0.74			
24				1.08	1.02	0.94	0.86	0.80		
25					0.92	0.86	0.81	0.75		
Monthly means		(1.35)	**1.20**	**1.08**	**0.99**	**0.89**	**0.84**	**0.77**	**0.74**	(0.76)
Departure from 12-year normal		**±0.00**	**+0.02**	**±0.00**	**−0.01**	**−0.03**	**−0.04**	**−0.04**	**−0.03**	**+0.05**
P. M.										
Nov. 2			1.18							
6	[1] 1.42		1.26	1.20	1.14	1.08	1.01	0.95	0.89	
9			1.05	0.84						
13				1.07	0.90	0.84	0.76	0.68		
14			1.17	1.12	1.04	0.97	0.90	0.85	0.79	
15			1.00	0.99	0.82	0.77	0.70	0.61	0.55	
17					0.88	0.81	0.75			
18			1.22	1.11	1.02	0.94	0.85	0.75	0.67	0.59
20					1.01	0.94	0.82	0.70		
24					1.10	0.96	0.90	0.86	0.83	0.79
Monthly means			**1.15**	**1.06**	**0.99**	**0.91**	**0.84**	**0.77**	**0.75**	**(0.69)**
Departure from 12-year normal			**−0.02**	**−0.02**	**+0.02**	**+0.02**	**+0.02**	**+0.01**	**+0.03**	**+0.01**

[1] Extrapolated and reduced to mean solar distance.

TABLE 1.—*Solar radiation intensities during November, 1919*—Continued

Madison, Wis.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Nov. 1			1.38	1.25	1.14	1.07				
11							1.03	0.97	0.93	
14			1.47	1.34	1.23	1.15				
15					1.11	1.05	1.02	0.95	0.91	
18	[1] 1.47		1.38	1.32	1.26	1.18	1.14	1.08	1.03	0.99
Monthly means			**1.41**	**1.30**	**1.18**	**1.11**	**1.06**	**1.00**	**0.96**	**(0.99)**
Departure from 10-year normal			**+0.10**	**+0.07**	**+0.02**	**−0.02**	**+0.03**	**+0.03**	**+0.08**	**+0.16**
P. M.										
Nov. 1				1.28	1.20					
5					1.02					
11				1.25						
12					1.21					
14				1.35	1.28	1.18				
18				1.31	1.22	1.16				
Monthly means				**1.30**	**1.19**	**(1.17)**				
Departure from 10-year normal				**+0.05**	**+0.02**	**+0.11**				

Lincoln, Nebr.

Date.	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.										
Nov. 1			1.24	1.09						
3			1.37		1.20	1.12				
5				1.18	1.09					
11				1.28	1.17	1.11	1.03			
12	[1] 1.56		1.42	1.37	1.28	1.21	1.14	1.07		
13			1.37	1.25	1.15	1.06	0.97			
14			1.42	1.28						
18					1.14	1.06	0.98	0.93	0.89	
Monthly means			**1.36**	**1.24**	**1.17**	**1.11**	**1.03**	**(1.00)**	**(0.89)**	
Departure from 5-year normal			**±0.00**	**−0.05**	**−0.05**	**−0.02**	**−0.04**	**−0.05**	**−0.09**	
P. M.										
Nov. 12	[1] 1.56		1.43	1.34	1.29	1.21	1.14	1.08	1.02	0.95
13	[1] 1.49		1.33	1.27	1.18	1.09	1.02	0.95	0.89	0.84
14			1.36							
15							0.88			0.76
Monthly means			**1.37**	**(1.30)**	**(1.24)**	**(1.15)**	**1.01**	**(1.02)**	**(0.96)**	**0.85**
Departure from 5-year normal			**−0.02**	**+0.01**	**+0.03**	**+0.02**	**−0.05**	**+0.02**	**+0.03**	**−0.05**

[1] Extrapolated and reduced to mean solar distance.

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.		
Date.	8 a. m.	8 p. m.	Date.	8 a. m.	8 p. m.	Date.	8 a. m.	8 p. m.
1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*
Nov. 2	6.50	4.95	Nov. 1	2.87	3.15	Nov. 1	3.15	4.37
3	4.17	7.04	5	3.00	4.37	3	5.16	2.87
5	3.81	4.37	11	2.36	3.30	5	3.15	5.36
6	4.17	4.37	12	2.06	1.45	11	3.30	1.96
9	4.95	5.36	14	2.26	1.37	12	1.07	1.60
13	7.87	3.00	15	1.68	2.62	13	1.96	3.63
14	2.49	3.99	18	3.30	2.36	14	2.36	2.74
15	3.00	3.81				15	2.62	4.95
17	4.37	6.50				18	4.57	4.17
18	5.16	3.15						
20	2.87	3.63						
24	4.37	4.17						
25	3.81	8.48						

TABLE 3.—*Daily totals and departures of solar and sky radiation during November, 1919.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Nov. 1	77	295	334	−175	104	91	−175	104	91
2	284	211	222	34	22	−19	−141	126	72
3	234	153	261	−14	−34	22	−155	92	94
4	146	214	288	−101	29	51	−256	121	145
5	251	208	276	6	25	41	−250	146	186
6	342	36	97	100	−145	−136	−150	1	50
7	203	100	50	−36	−78	−182	−186	−77	−132
8	173	44	36	−63	−132	−194	−249	−209	−326
9	286	35	51	53	−138	−178	−196	−347	−504
10	287	164	124	57	−7	−103	−139	−354	−607
11	22	262	260	−205	94	34	−344	−260	−573
12	102	259	362	−122	93	138	−466	−167	−435
13	253	261	335	33	98	112	−433	−69	−323
14	283	252	296	66	91	75	−367	22	−248
15	257	190	289	43	31	69	−324	53	−179
16	244	151	248	33	−5	30	−291	48	−149
17	256	171	268	48	17	51	−243	65	−98
18	270	228	248	64	76	33	−179	141	−65
19	171	189	283	−32	39	69	−211	180	4
20	263	197	181	63	49	−31	−148	229	−27

TABLE 3.—*Daily totals and departures of solar and sky radiation during November, 1919*—Continued.

Day of monthe	Daily totals.			Departures from normal.			Excess of deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Decade departure							−9	583	580
Nov. 21	224	31	275	27	−115	64	−121	114	37
22	63	217	245	−131	73	36	−252	187	73
23	248	185	242	56	43	34	−196	230	107
24	213	145	235	24	5	29	−172	235	136
25	147	26	58	−39	−112	−147	−211	123	−11
26	62	132	39	−122	−5	−164	−333	118	−175
27	225	155	118	44	19	−83	−289	137	−258
28	168	40	105	−11	−95	−93	−300	42	−351
29	40	32	231	−137	−102	35	−437	−60	−316
30	265	227	255	90	94	61	−347	34	−255
31	......	......	......	......	......	......	......	......	......
Decade departure							−199	−195	−228
Excess or deficiency since first of year:									
Gr.-cal							−7189	−4602	−4548
Per cent							−6.0	−4.0	−3.4

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Director.

[Dated: Astrophysical Observatory, Smithsonian Institution, Washington, Dec. 22, 1919.]

In continuation of preceding publications I give in the following table the results obtained at Calama, Chile, in October, 1919, for the solar constant of radiation. The reader is referred to this REVIEW for February, August, and September, 1919, for statements of the arrangement and meaning of the table.

The observers report that the cloudiness for the month of October exceeded that for any month since the beginning of their observations in July, 1918. If they were still dependent upon the old fundamental method of observing they would have secured not over 12 days' results during the month. They have worked up additional data as a basis for applications of the new method at times when the sun is very near the zenith and hereafter many of the results will be based on observations at air masses not exceeding 1.5.

Aside from the unusually broken series of observations during the month, the most outstanding feature is the unusually low value for October 7, which is strongly supported by three independent determinations—one by the old method and two by the new. As was stated in the last report, the average value of the solar constant for the month of September was about 1 per cent below that for the month of August and apparently the depression of solar radiation reached its minimum on October 7. Solar radiation then suddenly rebounded to a value above the average for the year and continued high and even reached values unusually high during the last decade of the month.

Date.	Solar Const.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity.			Remarks.
					$\rho/\rho sc$	V. P.	Rel. Hum.	
1919. October A. M.	*cal.*					*Cm.*	*P. ct.*	
2	1.944	E_0	G+	0.859	0.335	0.37	33	Cirri in east and west.
7	1.887	E_0	VG−	.839	.365	.16	15	Bank of cumuli in east.
	1.885	M_3	......	......	......	......	......	Some cirro-cumuli in west.
	1.912	M_2	......	......	......	......	......	
	1.891	W. M.	......	......	......	......	......	
1919. October A. M.	*cal.*					*Cm.*	*P.ct.*	
8	1.954	M_3	S	.865	.462	.19	17	
	1.967	M_2	......	......	......	......	......	
	1.963	W. M.	......	......	......	......	......	
9	1.942	M_3	S	.862	.492	.18	17	
	1.951	M_2	......	......	......	......	......	
	1.948	W. M.	......	......	......	......	......	
10	1.924	E_0	VG	.865	.438	.20	19	Distant cirri in northeast.
	1.975	M_3	......	......	......	......	......	
	1.964	M_2	......	......	......	......	......	
	1.961	W. M.	......	......	......	......	......	
11	1.955	M_3	S	.847	.442	.23	21	
	1.950	M_2	......	......	......	......	......	
	1.952	W. M.	......	......	......	......	......	
12	1.923	M_3	U+	.824	.420	.29	27	Cirri in west.
	1.962	M_2	......	......	......	......	......	
	1.949	W. M.	......	......	......	......	......	
13	1.929	M_3	S−	.848	.502	.24	27	
	1.954	M_2	......	......	......	......	......	
	1.946	W. M.	......	......	......	......	......	
14	1.931	M_3	S	.874	.609	.16	16	
	1.950	M	......	......	......	......	......	
	1.940	W. M.	......	......	......	......	......	
15	1.979	E_0	VG+	.857	.626	.13	15	
	1.958	M_3	......	......	......	......	......	
	1.954	M_2	......	......	......	......	......	
	1.959	W. M.	......	......	......	......	......	
17	1.934	$M_{1.33}$	S−	.856	.700	.25	14	Cirri over most of sky.
19	1.936	M_3	S−	.860	.526	.17	18	
	1.960	M_2	......	......	......	......	......	
	1.955	W. M.	......	......	......	......	......	
20	1 952	M_3	S+	.858	.506	.18	17	Low bank of cirri in east.
	1.954	M_2	......	......	......	......	......	
	1.953	W. M.	......	......	......	......	......	
21	1.968	E_0	VG+	.851	.476	.19	19	Distant cirri in south.
	1.978	M_3	......	......	......	......	......	
	1,958	M_2	......	......	......	......	......	
	1,965	W. M.	......	......	......	......	......	
A. M.								
23	1.950	M_2	S	.864	.588	.19	9	Cirri scattered about sky.
	1.938	$M_{1.02}$	......	......	......	......	......	
	1.946	W. M.	......	......	......	......	......	
24	1.970	E_0	G	.832	.508	.19	19	Cirri in north and east.
	1.958	M_2	......	......	......	......	......	
	1.962	W. M.	......	......	......	......	......	
25	1.964	$M_{1.5}$	S−	.855	.600	.23	19	Scattered cirri rapidly moving east.
26	1.971	M_2	S	.846	.471	.22	26	Some thin cirri scattered about, especially in west.
	1.971	M_2	......	......	......	......	......	
28	1.971	W. M.	......	......	......	......	......	
	1.957	$M_{1.2}$	S−	.860	.689	.25	18	Cirri around east, south and west, and very thin cirri over rest of sky.
31	1.958	$M_{1.21}$	S−	.847	.735	.15	10	Cirri scattered about sky, especially in east.

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By A. J. HENRY, Meteorologist.

Mean pressure in November in the Northern Hemisphere is characterized by a great continental HIGH over northern Asia, relatively high pressure in a belt which practically engirdles the globe about latitude 35° and two great areas of low pressure, the first over the ocean just west of Iceland, the other over the Aleutians extending thence westward to the Kamchatka Peninsula. The two chief centers of low pressure are connected by a trough of relatively low pressure in the polar regions. The weather in North America is largely controlled by the depth and persistence of the low pressure in the North Pacific and over the Gulf of Alaska, also by cyclones which form on the southern border of the semi-permanent HIGH in middle latitudes and move to the northeastward toward the Iceland LOW. Westerly winds prevail north of latitude 40° and variable winds to the south of that latitude.

The current month, judging from the information thus far at hand, was somewhat lacking in the frequency and severity of wind storms. Cyclonic systems of pronounced character were notably absent. The temperature was generally low and pressure high in Alaska, the Canadian Northwest, and the northwestern part of the United States. The details will be found elsewhere.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY, Meteorologist.

During the period from the 4th to the 11th stormy weather prevailed along the northern steamer route west of the one hundred and seventy-fifth meridian. Several vessels reported winds of force 9 and on the 7th one experienced a wind reaching force 10. There appear to have been two storms during the period, pursuing northeasterly courses to the east of Japan and the Kuril Islands.

From the 18th to the 22d a typhoon prevailed in the China Sea. Definite advices as to its course and intensity are yet lacking, however. The French S. S. *Admiral Latouche-Tréville,* Capt. J. Delamer, at Tourane, experienced northerly winds of force 10 on the 19th and 20th.

Several vessels reported winds of gale force in eastern parts of the ocean on the 3d and again on the 17th.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was slightly above the normal at land stations on the coasts of Newfoundland, Canada, and northern Europe, while it was slightly below in the West Indies.

A well developed LOW that covered the western section of the northern steamer lanes from October 29 to 31 were shown on Charts XII to XIV for that month. On November 1 this disturbance was central near latitude 53°, longitude 45° (see Chart IX), having moved but little since the previous day; the storm area had also diminished in extent, although winds of gale force still prevailed in the western and eastern quadrants. During the next two days the disturbance moved but little, and the winds west of the thirtieth meridian had moderated considerably, although on the 2d and 3d southeasterly gales still prevailed over the eastern part of the steamer lanes.

On November 6 there was a moderate disturbance central near latitude 42°, longitude 62° (see Chart X), that afterwards developed into quite a severe storm. The observer on board the Belgian S. S. *Eglantier* stated in the storm log that the gale began on the 6th. Lowest barometer reading 29.54 inches at noon, November 6, latitude 44° 03′ N., longitude 54° 06′ W. End of gale on 8th; highest force, 11. The easterly drift of this LOW was slight during the next 24 hours, as shown on Chart XI, and on the 7th strong northeasterly to easterly gales swept over the region between the center and the American coast. By the 8th (see Chart XII) the barometer had fallen and the storm area increased to some extent, although at the time of observation no winds of over 50 miles an hour were reported.

The observer on the British S. S. *Barbadian* reported that at Greenwich mean noon, November 10, while near latitude 31°, longitude 57°, several large water spouts passed close to the ship, and her course was changed to avoid them. On the 11th the *Barbadian* ran into a gale near Bermuda, the storm log being as follows: "Gale began at 9 p. m. on the 10th. Lowest barometer reading 29.73 inches. End of gale on the 12th; highest force, 11. Shifts of wind near time of lowest barometer E.-ESE.-E.-ENE." On both the 11th and 12th vessels near the *Barbadian* reported moderate northeasterly winds, the storm area evidently being of limited extent.

On the 13th the Italian S. S. *Burma* while near latitude 34°, longitude 31°, encountered a northerly gale of about 50 miles an hour. In the storm log the observer states that the gale began on the 12th. Lowest barometer, 29.61 inches at noon on the 12th; latitude 35° 53′ N., longitude 29° 30′ W. End of gale on the 14th; highest force of wind, 11. Shifts of wind WNW.-NW.-NNW.-N. Unfortunately no reports were received from vessels near the *Burma*, so it was impossible to determine the extent of the depression.

On the 18th there was a violent disturbance of limited extent off the coasts of Georgia and northern Florida. The American. S. S. *Limon* was some distance north of the center, and her storm log is as follows: "Gale began on the 17th. Lowest barometer 29.59 inches at 1 p. m. on the 18th; latitude 31° 30′ N., longitude 79° 02′ W. End of gale on the 20th; highest force of wind, 11. Shifts of wind N. NNE." During the next two days this disturbance decreased in intensity as it moved eastward, and on the 20th the center was near Bermuda.

From the 23d to the 25th a LOW of moderate intensity covered the greater part of the region between the twenty-fifth meridian and the British coast, where winds of from 40 to 50 miles an hour prevailed during this period, with hail on the latter date.

On the 29th there was a disturbance central near latitude 53°, longitude 27° (see Chart XIII), and strong northwesterly gales were reported over that part of the

steamer lanes between the 30th and 45th meridians, with hail and snow in the western section. This LOW moved slowly eastward, and on the 30th (see Chart XIV) the center was somewhere near latitude 56°, longitude 20°, although it was impossible to locate its position accurately on account of lack of observations. On this last day of the month winds of gale force prevailed over the greater part of the ocean east of the 40th meridian, north of the 45th parallel.

Fog was reported on five days from the Banks of Newfoundland, which is slightly below the normal for that region; it was reported on three days off the east coast of England, being comparatively rare over the other sections of the ocean.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

British Isles.—Nearly a dozen lives were lost in a severe hurricane which swept the waters around Goodwin Sands in the northern part of the Dover Straits. All attempts to reach stricken vessels were in vain, and several crews are believed to have perished.—*Washington Herald, Nov. 3, 1919.*

In and around the second week, * * * north Britain recorded [lowest November] temperatures * * * in at least half a century. * * * The bitter wintry weather was due largely, if not primarily, to the presence of an area of high barometric pressure over the Icelandic region. After the middle of the month, when depressions began to appear in the far north, the conditions resumed a more normal character, and, with a shift of wind to the west, temperature rose gradually, but very decidedly. * * * The general rainfall, expressed as a percentage of the average, was as follows: England and Wales, 82; Scotland, 110; Ireland, 79. Taken together October and November [in London (Camden Square)] had a mean temperature of 42.3°, the lowest in 62 years' record.—*Symons's Meteorological Mag., London, Dec., 1919, p. 137.* (*Cf. Nature, London, Dec. 25, 1919, pp. 417–418.*)

Belgium.—Heavy floods, and continued rain, were reported from all parts of Belgium. The Scheldt river rose over 6 feet, and the Sambre more than 7; the lower parts of Charleroi and of Mons were inundated.—*Washington Evening Star, Dec. 28, 1919.*

France.—Following closely upon the snowstorm of late October, snow again fell in various parts of France early in November. The fall in Paris was especially heavy, and was accompanied by intense cold. The Ardennes and Pyrenees are covered, the snow at one place reaching a depth of 3 feet. Marseilles is also suffering under the severe cold wave.—*New York Evening Post, Nov. 3, 1919.*

A blizzard struck Paris November 14, with 6 to 10 inches of snow the first night. Train and telegraph services were seriously interfered with, surface tramway cars tied up, and much suffering caused by the lack of coal.—*New York Evening Post, Nov. 15, 1919.*

Voters of Paris and all northern France trudged through 8 inches of snow to reach the polls, and in the south there had been storms and heavy rains. Paris had the heaviest snowfall in 75 years.—*New York Tribune, Nov. 17, 1919.*

Germany.—Urgent calls for brooms, shovels, wheelbarrows, and drays were made by the mayor of Berlin in the battle on steadily mounting snowdrifts. Streets are flanked with 4-foot snowbanks, and conditions in outlying residential sections are worse.—*New York Globe, Nov. 20, 1919.*

Berlin.—The weather in Berlin and throughout Germany, which had been very severe for the past week, has suddenly changed and today was almost warm. Rain made the thoroughfares almost impassable, the slush being many inches deep. Sewers are choked.—*By the Associated Press*, Nov. 20, 1919.

Spain.—A gale blew throughout Spain November 7. Three ships were driven ashore at Cadiz, while Malaga was partly inundated. Great damage was caused at Cordova, and there was a flood at Algeciras.—*New York Evening Post, Nov. 8, 1919.*

A heavy fall of snow and rain caused floods in many parts of Spain. No serious damage has as yet been reported, but Seville, Cadiz, and Huelvo are threatened. The floods inundated the town of Alcala de Henares, 17 miles east northeast of Madrid, but without loss of life.—*New York Sun, Nov. 17, 1919.*

South Africa.—There is now not the slightest doubt that this is the severest drought that South Africa has ever experienced. This is the opinion of Mr. Cronwright, the prinicpal sheep inspector, and I have to-day had the statistics of the meteorological stations of the border and midland districts placed before me dating from 1872.

These show that the severest season was in 1883, when only 12.65 inches of rain fell. The rainfall in 1884 was 12.70, and in 1885, 14.73—three terrible years. In 1903, which was a bad year, there were 15.78 inches, while in 1904 only 15.05. In 1908 only 13.69 inches of rain were recorded. All the foregoing were considered to be years of exceptional drought. Up to the present, and there are only six weeks to go, the year 1919 is far and away the lowest on record, as only 8.03 inches of rain have fallen.

A continuous heavy rain may alter this average, but the fact remains that since April no appreciable rain has fallen in these areas of the Union, where the crop and the stock prospects depend entirely upon the rain. * * *

In his opinion, the areas which had felt its effects worse were the midlands and the northwestern districts of the Cape, but the Free State was very badly affected. * * *

Taking the general average, the stock losses are not less then 35 per cent, while the crops are a total failure.—*Cape Times, Nov. 6, 1919.*

Australia.—Australia, especially New South Wales, during the month suffered the most devastating drought since white men have resided in the country. Stock and crops have been destroyed, and it is doubtful whether there will be enough seed wheat for next season's sowing. Hundreds and perhaps thousands of settlers have been ruined. Paddocks are littered with the skeletons of cattle; even rabbits are dying in vast numbers.—*Chicago Evening Post, Nov. 19, 1919.*

DETAILS OF THE WEATHER OF THE MONTH IN THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By A. J. HENRY, Meteorologist.

The tracks of 14 primary and 8 secondary cyclones have been plotted on Chart III. The great majority of these were without distinguishing features. The movement in latitude was more widely distributed than usual and there was an apparent lack of stability in most of the cyclones, as evidenced by the large number of secondaries that developed in the Rocky Mountain and Plateau region; also in the Northern Appalachian region. There was also a distinct tendency on the part of the cyclonic systems to assume the trough form east of the Mississippi. The track of cyclones plotted as III Ba and III Bb represent storms of widespread precipitation—snow in the mountains and rain in the lowlands. Near the close of the month a cyclonic system centered over southwest Arizona was apparently prevented from moving northeast by the pressure distribution over the plateau region. As it lingered over Arizona, flood-producing rains fell over that State, the first for several years. This cyclone finally moved east-southeast and appeared to dissipate over the mouth of the Rio Grande on the 25th. A few days later a fresh cyclone developed over Oklahoma and moved rapidly to the Lake Region as a storm of considerable energy. See track XIV.

Anticyclones.—Thirteen anticyclones have been plotted on Chart II All of these first appeared on the daily weather maps west of the 95th meridian, and like the cyclones a number of them dissipated before reaching the Atlantic. The Western Plateau region was occupied by an anticyclone from the 13th to the 18th and again from the 21st to the 23d. The southeastward movement of anticyclones was a feature of the month; four of the total number reached the Gulf States and apparently dissipated there. The movement of both cyclones and anticyclones during the month was more diverse than usual.

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, Jan. 2, 1919.]

PRESSURE AND WINDS.

The early part of the first decade of the month had pressure values generally below normal, particularly toward the south and east. No decided storm centers were apparent, however, until about the middle of the decade, when a low area that had moved eastward across the Great Lakes probably combined with another that apparently developed off the New Jersey coast and by the morning of the 5th appeared as a severe storm near the Massachusetts coast, with low barometer readings and high winds from New Jersey to Maine. This storm slowly dissipated eastward, strong winds continuing for a day or two along the New England coast.

The latter part of the decade had strong high pressure over northern districts, with low pressure in the South, the latter developing into a well-defined storm that had moved northward and was central at the end of the decade in the upper Mississippi Valley. This storm was attended by heavy rains in the central valleys and by snows to the north and west of the center, the falls being particularly heavy in portions of eastern Colorado and western Nebraska. Early in the second decade high pressure overspread the Northwest and cold weather for the season prevailed for several days over most districts, the temperature falling to 20° below zero at points in Wyoming, and to freezing, or lower, in the interior of the Gulf States. Moderate pressure prevailed during the remaining portion of the second decade, but with a rising tendency, so that by the end it was well above normal over most eastern districts and high and rising to westward of the Rocky Mountains.

Pressure continued high in the West for several days, but in the East it rapidly gave way, and by the middle of the last decade pressure was low and falling from Texas northeastward to the lower Lakes and stormy conditions prevailed for several days over the eastern and southern districts, with heavy precipitation in the central valleys. At the same time high pressure was advancing into the upper Missouri Valley, the barometer reading at Havre, Mont., rising above 31 inches, the highest ever observed at that point. Low temperatures prevailed over all northern districts for several days, extending southward and westward over the Plains and Mountain districts, where the lowest temperatures for the month were generally observed. Near the close of the month pressure had fallen over central and eastern districts and a storm of wide area, attended by rain or snow, moved during the last two days from Texas northeastward to the Lower St. Lawrence Valley. At the same time high pressure and cold weather were again advancing into the Northwest.

The average pressure for the month showed the highest area extending as usual from the South Atlantic States northwestward to the northern Rocky Mountain and Plateau regions, with the maximum pressure, 30.20 inches, sea level, over central Wyoming. Pressure was lowest over the far Southwest, where the negative departures from the normal were likewise the greatest. The average pressure was above normal in southern Canada and generally over the northern and central portions of the United States, but in the most southern sections the averages for the month were less than normal.

November was a month with more wind than is usual over extensive areas, in fact several stations report the wind movement as greater than in any previous November. Winds were especially high and damaging at points on the New England coast on the 5th and 6th and in the vicinity of western Lake Erie on the 29th and 30th, where they were as high as, or higher than, ever before observed. The prevailing wind directions were mostly north to west along the Atlantic and Gulf coasts and over much of the interior of the country. In portions of the Ohio Valley and the Lake region they were frequently from the south or southwest and these directions prevailed extensively in the far Northwest.

TEMPERATURE.

November opened with unseasonably high temperature in the Ohio Valley and thence southeastward, but from the upper Lakes westward and southwestward cold weather for the season prevailed.

During the next few days considerably colder weather overspread the Atlantic Coast States, with frost from Virginia northward and in the Ohio Valley, and there was a general rise in temperature over most western districts, except that it was much colder in the Dakotas and adjacent States on the 4th. During the latter half of the first decade cool weather for the season prevailed in the Plains region and thence westward, but the daily

changes were usually not marked, and moderate temperatures were the rule in the central and eastern districts, some of the highest readings of the month being reported on the 9th and 10th in the central valleys. Early in the second decade, cold weather overspread nearly all portions of the country, the temperature falling to 20° below zero in Wyoming, and to freezing in the interior of the Gulf States. The latter half of the second decade was without marked temperature changes, but with a general tendency to warmer weather, although over much of the country the temperatures were frequently below normal. During the early part of the third decade moderate temperatures occurred in extreme eastern districts, but elsewhere important changes were infrequent and on the whole moderate weather prevailed. About the middle of the decade a severe cold wave overspread the Missouri Valley and during the following few days extended over much of the country. The lowest temperatures for the month were reported in the northwest, and far western States, but in the south and east the temperatures were not so low as on previous dates. The month closed with cold weather for the season over most southern districts, and a moderate cold wave was advancing into the Missouri Valley.

For the month as a whole the temperature averaged much below normal in the Missouri Valley and adjacent districts, and somewhat below over the remaining districts to westward of a line from central Texas northeastward, to the upper Lakes. The month was warmer than normal from the central and lower Mississippi Valley eastward and northeastward. Over portions of the upper Missouri Valley and northern Rocky Mountains November was far colder than normal, and following the unprecedented cold of October completed an autumn of unusual severity. On the other hand, over the southeastern States, November was unusually warm, in fact at some points it was the warmest November in nearly fifty years, and this following the unprecedented heat of October and above-normal temperatures for September constituted an autumn of unusual warmth.

Maximum temperatures about the first of the month were unusually high along the Atlantic coast, particularly from Maryland southward where at points they were the highest ever recorded in November.

Minimum temperatures over western districts were low for November, but in only a few cases, notably in California, were they below previous records. They were below zero from western Texas northeastward to the upper Lakes and thence westward to the Sierra Nevada and Cascade Mountains, the minimum reported being 36° below zero in North Dakota on the 27th, at which time the lowest temperatures of the month were recorded in most of the Mountain, Plateau, and Pacific States. East of the Mississippi, except in Wisconsin and Michigan, and locally in northern New England, minimum temperatures did not fall below zero and they were not lower than 20° in the Gulf or South Atlantic States, except in the higher mountains.

PRECIPITATION.

During the first few days of the month precipitation occurred in most eastern districts and also in the far Northwest, and toward the middle of the first decade rain or snow again fell over the northeastern districts and light rain was received in the far Northwest. Toward the latter part of the decade a precipitation area overspread the western Plateau States and moving eastward and northeastward, developed into a storm of wide extent by the end of the decade, and during the first few days of the second decade extended over most eastern districts. It brought unusually heavy rains in portions of the central Valleys and west Gulf States, and heavy snows in eastern Colorado and western Nebraska, and lighter falls over most northern districts from the Great Lakes westward. Throughout much of the second decade there were frequent rains or snows on the North Pacific coast and occasionally in the Lake region, but in the main fair weather prevailed.

About the beginning of the third decade precipitation occurred in the central Plateau districts, and locally in the Southwest during the following few days, and later in the decade light rain or snow was rather frequent from the region of the Great Lakes eastward and also in parts of the far Northwest. The last half of the decade was marked by much stormy weather and precipitation occurred in most sections of the country, except in the Southeast. Heavy rains occurred over the central valleys and portions of the far Southwest, and heavy snows were reported from the mountain districts of California, Utah, Arizona, and portions of adjoining States.

For the month as a whole the precipitation was heavy to excessive over a considerable area extending from the lower Mississippi Valley and northeastern Texas northeastward over the immediate Ohio Valley, where the general average was from 6 to 12 inches with local falls of from 15 to 18 inches. Heavy falls were also recorded in portions of Florida and in the higher elevations of the far Northwest, and some unusually large amounts for the season and region were received in northern Arizona. The month was dry in California, where only very light precipitation for the season occurred until near the end, except in portions of the mountain districts. Over the South Atlantic States, November was practically rainless, particularly over the eastern portions of the Carolinas and Georgia, and severe drought prevailed. Precipitation was deficient in the eastern Lake region, while from the upper Lake region and the Mississippi Valley southwestward to the Rocky Mountains the falls were mainlly above the seasonal average, more than twice the monthly normal being received in many localities.

SNOWFALL.

Snowfall was heavy in the western mountain districts and also over the area from the upper Lakes to the Rocky Mountains, the ground being covered with snow during much of the month in these sections. At Houghton, Mich., more than 5 feet of snow fell during the month, and points in northern Arizona, southern Utah, and adjoining areas had unusually heavy snows toward the end of the month. In portions of the northern Plains and Rocky Mountains the ground remained snow-covered during practically the entire month, a condition that prevailed also during the last decade of October. The severe cold and lack of opportunity for range-grazing caused much suffering, and some loss of stock where provision could not be made for feeding or moving.

Over the eastern part of the country, the snowfall was generally light and but little remained on the ground at the end of the month save in extreme northern New England.

RELATIVE HUMIDITY.

From the Mississippi River westward to the Plateau region, the relative humidity was nearly everywhere above the normal, the excesses being quite large, particularly at the evening observation over the Missouri River and northern Mountain districts. Along the Pacific coast relative humidity was below normal, the deficiencies

being particularly large in northern California and southern Oregon. Over the districts from the Mississippi River eastward, the relative humidity was not far from normal but mostly slightly less, particularly over the south Atlantic coast.

Unusually low relative humidity was observed over the Florida Peninsula on the 18th and 19th, the values were lowest over the northern districts on the 18th and over the extreme southeast on the 19th, the lowest observed was 22 per cent at Miami. These readings were in connection with a low barometer off the east Florida coast which caused strong northwest winds over the mainland, but this evidently did not wholly produce the low moisture content of the air, as inland stations farther north had much higher values of both relative and absolute humidity.

SAND STORMS.

At the U. S. Naval air station, San Diego:

November 21 and 22, sand storms came up, reaching their greatest violence about noon each day, with a maximum wind velocity of about 50 miles per hour, and the bumpiest air conditions at all altitudes experienced at this station during the current fiscal year.

Average accumulated departures for November, 1919.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	0-10.		P. ct.	
New England	40.1	+1.1	+17.0	3.92	+0.40	+ 2.31	6.9	+0.8	78	+ 2
Middle Atlantic	45.8	+1.5	+26.4	2.72	−0.20	− 2.90	5.7	+0.3	74	0
South Atlantic	57.4	+3.3	+21.9	0.59	−2.20	− 7.90	5.0	+0.6	73	− 3
Florida Peninsula	73.5	+2.5	+ 3.5	3.73	+1.50	+ 4.20	4.6	+0.4	75	− 5
East Gulf	59.9	+4.4	+15.0	4.26	+0.70	+ 9.46	5.3	+0.8	77	+ 2
West Gulf	57.4	+1.0	−2.0	3.83	+0.80	+10.45	5.0	+0.3	77	+ 4
Ohio Valley and Tennessee	45.5	+0.9	+20.4	4.61	+1.20	+ 3.40	5.6	0.0	75	+ 2
Lower Lakes	38.8	−0.3	+22.4	1.57	−1.40	+ 0.30	7.4	+0.1	74	− 2
Upper Lakes	32.9	−1.4	+29.8	3.32	+0.90	− 1.40	7.5	+0.4	79	− 1
North Dakota	15.8	−8.7	+11.7	1.08	+0.30	− 2.15	5.5	0.0	85	+ 6
Upper Mississippi Valley	36.9	−0.9	+21.7	3.18	+1.20	+ 3.10	6.1	+0.6	75	+ 1
Missouri Valley	34.9	−2.5	+18.2	2.62	+1.40	− 1.50	5.6	+0.7	76	+ 6
Northern slope	25.4	−6.7	+11.1	1.44	+0.60	− 1.70	5.2	+0.1	74	+ 5
Middle slope	39.2	−2.6	+ 5.8	1.60	+0.60	− 3.33	4.3	+0.3	71	+ 8
Southern slope	49.4	−1.5	−11.0	1.55	+0.40	+ 0.60	4.8	+0.4	70	+ 4
Southern Plateau	48.4	−0.5	+2.2	0.87	+0.30	+ 1.59	3.0	+0.2	53	+ 5
Middle Plateau	37.1	−2.5	+3.4	0.82	−0.10	− 2.40	3.9	−0.4	60	− 1
Northern Plateau	36.5	−2.2	+7.9	2.00	+0.60	− 2.10	6.5	+0.4	75	+ 4
North Pacific	44.9	−0.7	+6.7	6.39	−0.60	− 7.20	8.0	+0.4	85	− 1
Middle Pacific	52.0	−1.0	−7.2	0.88	−2.30	− 5.10	3.3	−1.4	59	−16
South Pacific	57.4	−0.2	+4.1	0.27	−1.00	− 4.70	2.0	−2.4	56	−11

Winds of 50 mi./hr. (22.4 m./sc.), or over, during November, 1919.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
Block Island, R. I.	5	69	nw.	Mount Tamalpais, Calif.—Con.			
Do	6	54	nw.	Do	26	84	n.
Do	30	52	w.	Do	27	88	n.
Buffalo, N. Y.	4	54	w.	Do	28	52	n.
Do	11	54	w.	Do	30	56	nw.
Do	12	52	w.	Nantucket, Mass.	5	54	ne.
Do	14	56	sw.	Nashville, Tenn.	29	55	se.
Do	18	50	w.	New York, N. Y.	4	50	nw.
Do	22	56	sw.	Do	5	59	nw.
Do	29	76	sw.	Do	6	61	nw.
Do	30	82	sw.	Do	19	58	nw.
Burlington, Vt.	11	52	s.	Do	20	60	nw.
Cairo, Ill.	29	56	sw.	Do	30	58	nw.
Canton, N. Y.	29	57	sw.	North Head, Wash.	4	52	nw.
Do	30	53	w.	Do	5	52	se.
Cheyenne, Wyo.	1	52	w.	Do	6	50	se.
Do	2	66	w.	Do	7	54	nw.
Chicago, Ill.	10	50	sw.	Do	15	68	s.
Do	29	50	sw.	Point Reyes Light, Calif.	2	51	nw.
Cleveland, Ohio	29	60	w.	Do	3	50	nw.
Columbus, Ohio	29	52	s.	Do	4	50	nw.
Do	30	50	w.	Do	7	73	nw.
Dayton, Ohio	29	56	sw.	Do	19	67	nw.
Detroit, Mich.	29	87	sw.	Do	26	64	nw.
Duluth, Minn.	29	53	nw.	Do	27	61	n.
Eastport, Me.	5	72	ne.	Port Huron, Mich.	29	76	w.
Do	6	56	ne.	Providence, R. I.	5	52	nw.
Ellendale, N. Dak.	10	66	nw.	Do	30	55	w.
Erie, Pa.	29	54	s.	Saginaw, Mich.	29	53	sw.
Do	30	54	sw.	Sandusky, Ohio	29	68	sw.
Evansville, Ind.	29	67	sw.	Do	30	54	sw.
Fort Wayne, Ind.	29	66	sw.	Sandy Hook, N. J.	5	64	nw.
Grand Haven, Mich.	29	56	sw.	Do	6	50	nw.
Green Bay, Wis.	10	56	sw.	Do	30	50	sw.
Do	20	50	sw.	San Francisco, Calif.	26	60	n.
Indianapolis, Ind.	29	58	sw.	Do	27	62	ne.
Keokuk, Iowa	10	63	sw.	Sioux City, Iowa	10	52	w.
Louisville, Ky.	29	58	sw.	St. Louis, Mo.	29	64	sw.
Lexington, Ky.	29	62	sw.	St. Paul, Minn.	10	50	s.
Ludington, Mich.	10	54	sw.	Syracuse, N. Y.	29	52	s.
Mount Tamalpais, Calif.	2	50	nw.	Tatoosh Island, Wash.	3	60	e.
Do	4	72	nw.	Do	11	53	e.
Do	5	58	nw.	Do	14	58	s.
Do	7	64	nw.	Do	15	64	s.
Do	8	50	n.	Do	16	61	s.
Do	18	64	nw.	Toledo, Ohio	29	82	sw.
Do	19	62	nw.	Do	30	57	sw.
Do	20	58	n.				
Do	25	74	nw.				

SPECIAL FORECASTS AND WARNINGS. WEATHER AND CROPS.

WEATHER WARNINGS, NOVEMBER, 1919.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Dated Weather Bureau, Washington, Dec. 22, 1919.]

STORM WARNINGS.

The storm of November 29 and 30.—This storm was the only great storm of the month, and, measured by pressure and wind velocity conditions, it was perhaps the greatest Great Lake storm since November, 1913. It followed the abnormal development of a disturbance over the Southern Plateau at a time when marked high pressure prevailed over the entire northern and central sections of the country from the Rocky Mountains to the Atlantic Ocean, and was first noticed on the morning of the 28th as a very moderate depression over southeastern Texas. By the evening of that day the depression had moved northward to southwestern Arkansas, and pressure had fallen decidedly over the entire interior of the country east of the Rocky Mountains, and at 9:40 p. m. advisory warnings for Lake Michigan were issued. Pressure continued to fall rapidly during the night and by the morning of the 29th the disturbance had attained the proportions of a great storm, being central at the time over northern Illinois with a lowest barometer reading of 29.30 inches. Winds had increased considerably to the eastward, but not to the northward. Storm warnings were at once ordered at all Lake stations and strong winds and gales forecast. Northwest warnings were ordered for Lakes Superior and Michigan, and southwest warnings for Lakes Huron, Erie, and Ontario, to be changed to northwest at sunset on Lake Huron. Southwest warnings were also ordered displayed at 12:00 noon along the Atlantic coast from Eastport, Me., to Delaware Breakwater, Del., and southeast warnings southward to Jacksonville, Fla. Small-craft warnings were ordered displayed along the east coast of the Gulf of Mexico for fresh to moderately strong southwest to west winds.

Special observation taken at 1:00 p. m. showed that the storm was still rapidly increasing in intensity, and at 3:00 p. m. the following warning was issued to all Lake stations:

"Storm centered 1:00 p. m. over southern Wisconsin, greatly increased intensity. Dangerous winds all Lakes tonight and Sunday shifting on upper Lakes, becoming northwest; generally south and southwest on lower Lakes to-night, shifting to west and northwest Sunday. Snow and much colder. Caution all vessels to observe every precaution for safety."

The storm was then central over southern Wisconsin with barometer readings slightly below 29 inches, and with increasing winds, while to the southward a quick recovery in pressure had set in attended by clearing weather and strong winds and gales, the strong winds extending down to the Gulf coast. By 8:00 p. m. the storm center had passed to the northeastward of Lake Superior (pressure at Sault Ste Marie 28.58 inches), and the barometer was rising as far north as the southern limits of Lake Michigan. On the morning of the 30th the storm center was probably some hundreds of miles east of James Bay (barometer at Father Point, Canada, 29.06 inches, with fresh winds from the southwest), and the warnings on the Atlantic coast were ordered changed to northwest. The northwest warnings were also continued until sunset on the upper Lakes. By the morning of December 1 the storm had disappeared beyond the field of observation.

The winds during this storm blew with force ranging from fresh gales to hurricanes. The greatest hourly velocities attained on the Lakes were 72 miles at Port Huron, Mich.; 84 miles at Detroit, Mich.; 80 miles at Toledo, Ohio, and Buffalo, N. Y.; but notwithstanding these extreme velocities, there was not a single marine casualty—probably a hitherto unprecedented occurrence for a storm of such great magnitude and intensity. There was, however, considerable damage done on shore and over interior districts southward through the Ohio valley and Tennessee. Along the Atlantic coast the winds were not so violent, New York City reporting a maximum velocity of 64 miles an hour from the northwest.

Other warnings.—Special 1 p. m.-observation on November 3 indicated falling pressure over the Great Lakes, with a rapid rise to northwest, and at 3 p. m. northwest-storm warnings were ordered for Lake Michigan and for central and western Lake Superior. Pressure continued to fall over the Lakes, and on the morning of the 4th the warnings were extended over eastern Lake Superior and Lake Huron. Southwest warnings were also ordered for Lake Erie and at 3:30 p. m. for Lake Ontario. Strong winds occurred generally as forecast. By 8 p. m. of the 4th the principal center of disturbance was over Ontario, with a secondary one over eastern Maryland, and at 9:30 p. m. northeast storm warnings were ordered along the New England coast from Point Judith, R. I., to Eastport, Me. By the morning of the 5th there was a single severe disturbance just off the Massachusetts coast, with gales that extended westward to the northern New Jersey coast. The storm continued northeastward, and at 9:30 p. m. the warnings on the Maine coast were changed to northwest. Strong winds occurred on the 5th, as forecast, and also persisted over the ocean to the southward. Unusually high tides prevailed during the passage of this storm, and for a day or two after, causing great damage along the coast from New York northward almost to Maine. The damage was estimated at more than $1,000,000.

On the morning of the 9th a disturbance from the north Pacific Ocean was central over western Texas and small-craft warnings for the fresh to moderately strong easterly winds that followed were ordered along the Gulf coast from Bay St. Louis, Miss., to Carrabelle, Fla. By 8 p. m. the storm center was over southeastern Nebraska, with increased intensity, and at 10 p. m. southeast-storm warnings were ordered on Lakes Superior and Michigan, and on Lake Huron from Saginaw, Mich., northward. By the morning of the 10th the storm had developed into a severe one, with its center over southern Minnesota, and with strong high pressure over the Middle Atlantic States and New England, and the southeast warnings were extended over the entire Great Lake area, south and southwest gales being forecast. At 1 p. m. the storm center was over extreme western Lake Superior, and at 3 p. m. orders were issued to change all warnings

to southwest at sunset, except along Lake Superior west of Houghton, where northwest warnings were ordered. General gales occurred as forecast, the storm continuing northeastward toward James Bay.

On the morning of the 17th there was a disturbance off the southeast coast of Florida, and advisory warnings of possibly increasing winds were issued. Conditions became somewhat more pronounced by 8 p. m., and at 9:30 p. m. northwest storm warnings were ordered from Miami to Jacksonville, Fla., and northeast warnings to the northward as far as Georgetown, S. C. At the same time a disturbance from the Canadian northwest was central north of Georgian Bay, with an apparent tendency toward increased development, and at 10 p. m. southwest-storm warnings were ordered from Cleveland, Ohio, to Oswego, N. Y., and strong winds occurred on the lower lakes on the 18th and extended northward over Lake Huron. The South Atlantic disturbance continued to develop, and at 11 a. m. of the 18th the northeast warnings were extended northward to Fort Monore, Va. By 8 p. m. there was a secondary disturbance over southern New England and northwest warnings were ordered from Sandy Hook, N. J., to Provincetown, Mass. Reports received by radio indicated the occurrence of gales a short distance off the South Atlantic coast, but no strong winds were reported from coast stations. Along the northern coast strong winds and gales occurred.

As the low pressure still persisted off the Atlantic coast northwest-storm warnings were ordered at 3 p. m. November 19 from Hatteras, N. C., to Atlantic City, N. J., to be lowered at 8 a. m. of the 20th, and at 7 p. m. the northwest warnings from Sandy Hook to Provincetown were ordered continued for another day. These warnings were fully verified.

From the 21st to the 24th, inclusive, a disturbance moved eastward over Canada and the northern tier of States with increased intensity, but with its center north of latitude 48°, and no warnings were ordered for the strong winds of short duration that occurred during the 22d over Lake Erie and southern Lake Huron. At 10 p. m. of that date northwest warnings were ordered for Lake Ontario and southwest warnings along the Atlantic coast from Delaware Breakwater to Eastport, Me., the storm center at that time being over northern Ontario. These warnings were not verified, only fresh to moderately strong winds occurring.

On the evening of the 24th another northwestern disturbance was central over eastern Kansas in moderate form, with a cold high area developing rapidly to northward, and at 10:00 p. m. northeast-storm warnings were ordered on Lake Superior and northern Lake Michigan, snow, with strong northeast to north winds being forecast, to be followed by a cold wave on the night of the 25th. On the morning of the 25th the center of the disturbance was over southern Michigan, with about the same intensity, but the cold high area to the northwestward had increased decidedly in magnitude and intensity, and northwest warnings were accordingly ordered for southern Lake Michigan and Lakes Huron and Erie, forecasts of snow with a cold wave being included in the warning. At 3 p. m. the warnings on Lake Superior and northern Lake Michigan were changed to northwest. The storm did not develop further, and the warnings for the lower Lakes were not verified, although they were fully justified on the upper Lakes. This disturbance extended in trough shape from northeast to southwest, and on the morning of November 26, a secondary development of the southwestern section was central over eastern Kentucky, with continued cold and still higher pressure to the northwestward, and at 3:00 p. m. northeast warnings were ordered on the lower Lakes, strong northeast to north wind, with snow, being forecast. These warnings were verified for the most part.

Marine casualties.—Some casualties occurred along the southern New England coast during the high winds of November 5 and 6, but there were none on the Great Lakes, except on Superior, where, unfortunately, several major disasters occurred, with the loss of a considerable number of lives.

Panama northers.—A warning of increasing northeast winds becoming strong by November 14 or 15, was sent to the Panama Canal Zone on the 13th. Strong north winds occurred for several days, but, contrary to previous experience, they began from 24 to 36 hours earlier than had been forecast. The maximum wind velocities reported by Mr. R. Z. Kirkpatrick, chief hydrographer of the Canal Zone were 25 miles an hour from northeast at Colon on November 12 and 50 miles an hour from north at Cape Mala on the 13th. The type of pressure distribution prevailing when the warning was issued was one of generally strong and high pressure over the United States with the crest over the west Gulf States and low pressure over the Caribbean Sea and the Middle Atlantic Ocean.

COLD WAVES AND FROSTS.

Although the high area on the second day of November, following the disturbance of the few previous days was of moderate character only, the accompanying temperatures to westward were rather low, and warnings of frost for the morning of November 3 were issued for the lower Lake region, the upper Ohio Valley, Tennessee, the higher districts of the Carolinas, the middle Atlantic States and southern New England. These frosts occurred generally as forecast, except in the Carolinas. There were no other frosts of consequence for some time, except the killing frost of the morning of the 5th over the Ohio Valley, for which no warnings had been issued, although much colder weather had been forecast.

The first cold-wave warning of the month was issued on the evening of the 11th and covered Michigan and Indiana. At the time a moderate disturbance was over southeast Kansas moving northeast, with a cold and extensive high area covering the northwest. On the morning of the 12th, with the center of disturbance over upper Michigan, the cold-wave warnings were extended through the western upper Lake region, the Ohio Valley, Tennessee, and the lower Mississippi Valley. A moderate cold wave followed on the morning of the 13th, except in eastern lower Michigan and the lower Mississippi Valley, where the fall in temperature was not sufficient to justify a cold-wave warning, although the temperatures were quite low for the season. High pressure and low temperatures prevailed over the interior of the country, and cold-wave, freezing-temperature and frost-warnings were issued quite generally for the middle and south Atlantic and the east Gulf States. These warnings were also verified on the morning of the 14th, except along the south Atlantic coast and over northern Florida, where cloudy weather continued. Frost-warnings were again issued for South Carolina, northern Florida, and the east Gulf States, and were verified on the morning of the 15th except in northeastern Florida.

Nothing further developed until the evening of the 24th when high and rising pressure and low and falling temperatures prevailed over the Canadian Northwest, and a disturbance of fair proportions was over the lower Mis-

souri Valley moving eastward. Cold-wave warnings were issued at 10 p. m. for Michigan, and extended on the following morning over the western lower Lake region, the Ohio Valley, Western Tennessee and extreme northern Mississippi. A secondary disturbance developed during the night of the 24th–25th over the lower Arkansas Valley, while the northern disturbance moved slowly, and pressure over the Middle Atlantic States rose considerably. The fall in temperature was consequently interrupted, and the cold-wave warnings failed generally of verification.

By the evening of November 26, pressure was falling over the Atlantic Ocean, was low over the Atlantic States with high temperatures and still abnormally high over the northwest. Cold-wave warnings were accordingly ordered for the Middle and South Atlantic States, except Florida. It happened that an offshoot from the northwestern high area moved rapidly eastward, causing northeast winds, with generally cloudy weather, and there were no cold waves.

Following the great storm of November 29, cold-wave warnings were ordered for the Lake region, the Ohio and Mississippi Valleys, and the Atlantic States as far south as Georgia. These warnings were almost entirely verified by the occurrence of a general cold wave over the districts covered by the warnings.

WARNINGS FROM OTHER DISTRICTS.

Chicago (Ill.) Forecast District.—The month was marked by rapid storm movement over the district during the first and third decades, with unsettled conditions and more or less precipitation and variable temperature, while in the second decade the conditions were much different, as a rule, moderate temperature and fair weather, in fact the so-called Indian summer type then prevailing, especially in the eastern and southern portions of the forecast district.

The mean temperature for the entire month was far below the normal in the Northwest, and generally below the normal in all portions of the district, except the Lake Michigan region and middle Mississippi Valley. The lowest temperature recorded was $-20°$ at Williston, N. Dak., and Lander, Wyo., and zero temperatures extended well into the central Great Plains.

At the beginning of the month all crops had fully matured and had been harvested in practically all portions of the district, except southern Illinois and eastern and southern Missouri and, as a consequence, frost-warnings were necessary only in the last-named sections.

On the 1st, advices for frost were sent to these places in advance of a cold wave pushing eastward, and heavy-to-killing frosts were reported on the morning of the 2d, thus terminating the frost-warning season for 1919.

The first cold-wave warning of the month was issued on the 3d in advance of a cold wave which appeared in Alberta on the morning of that day, advices being sent to northern and western Minnesota, Kansas, Illinois, Missouri, and Wisconsin, and the greater portion of Iowa, and by the morning of the 4th the lowest temperatures noted this season were then reported from the Plain States eastward over the upper Mississippi Valley. The cold wave, however, was followed by rapid recovery throughout the middle western sections. By the morning of the 6th another cold wave overspread the northern Plains States, and, although colder weather was predicted for the area affected, the marked fall in temperature was not anticipated. Warnings, moreover, were issued on the morning of the 6th to the districts to the south and east as far as the Mississippi River in anticipation of the eastward movement of this wave; but because of the passage of the high-pressure area far to the north, with accompanying unsettled conditions and northeast winds, the cold wave was rapidly dissipated.

On the morning of the 7th a depression was centered over the middle plateau, and, as it promised to develop in its movement southeastward and be followed by winds shifting to northerly and by colder weather, precautionary advices were sent to live-stock interests in Wyoming, South Dakota, Nebraska, and Kansas. At the same time cold-wave warnings were issued to stations in northern and central portions of the Great Plains. By the morning of the 9th the center of the disturbance had reached Texas. It then changed its course and moved directly northeastward, accompanied by shifting gales and colder weather, with snow on its western side. By the 11th another disturbance had appeared in the plateau which advanced rapidly eastward and was followed by a cold wave over the greater portion of this forecast district. Cold-wave warnings were issued to most stations well in advance of the fall in temperature, and at the same time special advices were sent to stock interests in Wyoming, Nebraska, and Kansas of snow and strong northerly winds, as well as cold weather. This wave proved general and unusually severe for the season of the year.

Then ensued a period of comparatively settled weather, and it was not until the morning of the 24th that another cold wave appeared in the British northwest. This rapidly forced its way southward over the Great Plains and upper Mississippi Valley, with a decided fall in temperature and rather strong northerly winds and some snow; but in the sections east and south the severe conditions were not felt, as the center of the high-pressure area remained far to the north, with resulting northeast winds and cloudy weather. Cold-wave warnings and advices to stock interests were, however, telegraphed to the sections affected well in advance of the storm.

A disturbance, centered in the west Gulf region on the 28th, moved directly northeastward over the upper Lakes by the 29th, and, as at the same time a cold wave had appeared in the British Northwest, warnings were issued to live-stock interests in the Plains States on the morning of the 28th, and cold-wave warnings on the 29th to points in the upper Mississippi Valley eastward over Illinois and Wisconsin. As the temperature had risen considerably in the Middle States in advance of the disturbance, the ensuing falls in temperature were quite marked, and the accompanying gales were severe.

The month closed with unusually low temperatures over the entire forecast district.—*H. J. Cox.*

New Orleans (La.), Forecast District.—Storm warnings for strong northerly winds were ordered displayed on the east coast of Texas on the 12th and 27th, because of areas of high barometer moving southward. The winds attending these HIGHS, however, were not very strong on the coast, although moderate gales have occurred previously with maps of similar barometric gradient. No general storm without warnings occurred.

Small-craft warnings were displayed on the Louisiana and Texas coasts on the 9th and on the Louisiana coast on the 29th, and were justified.

Cold waves of unusual severity for the season occurred in the northwestern portion of the district but did not reach the coast sections.

On the p. m. map of the 3d, a trough of low pressure was over the Mississippi Valley and the West Gulf

States and a moderate area of high pressure and colder weather overspread the eastern slope of the northern Rocky Mountain Region. On these conditions, cold-wave warnings were ordered for the Texas Panhandle, Oklahoma, and Bentonville, Ark. The temperature dropped sharply on the 4th but was not low enough for a cold wave, the change to colder being neutralized by an area of low pressure from the North Pacific coast, which was central over southeastern Wyoming on the morning of the 5th.

On the morning of the 8th a well-defined area of low pressure was central over northeastern New Mexico and an extensive high area was over western Canada. Cold-wave warnings were ordered for the same area as on the 3d and were extended, after the receipt of special observations, over northwestern Texas as far east as Dallas. A cold wave occurred in the extreme northwestern portion of the district, but before it could extend farther, the southwestern low, which at first moved southward, changed its course and moved northeastward and the high pressure diminished rapidly.

During the afternoon of the 11th an area of high pressure and colder weather was moving southeastward from western Canada and Montana, preceded by a shallow trough of low pressure. Cold-wave warnings were ordered, on the p. m. map, for Oklahoma, Arkansas, west Texas, and the northern portion of east Texas, and were extended the next morning over northern Louisiana and the remainder of Texas except the immediate coast. These warnings were verified.

The p. m. map of the 24th showed an area of high pressure moving southward from the interior provinces of western Canada, preceded by low pressure over the upper Mississippi Valley and the southern Plains States. Cold-wave warnings were issued for Oklahoma and the Texas Panhandle. The warnings were extended on the morning of the 25th over Arkansas, and at night over northern Louisiana and the northern portion of east Texas. Low pressure developed over the southern Rocky Mountain Plateau and prevented the cold wave from reaching the southern and eastern portions of the district, although a cold wave occurred in Oklahoma and northwestern Texas. As the cold wave still threatened on the morning of the 26th, midday special observations were obtained and cold-wave warnings were issued for the entire district except southern Louisiana and the southeastern portion of east Texas, but the warnings were extended over the southeastern portion of east Texas on the night of the 26th and southern Louisiana on the morning of the 27th. The warning issued in the afternoon of the 26th stated that the cold wave would be severe in Oklahoma and northwestern Texas, with strong northerly winds. Conditions occurred as forecast in the northwestern portion of the district, but the cold wave reached only the interior portions of Texas and did not extend over Arkansas and Louisiana. The southwestern LOW after being forced southwestward to the southern California coast, moved eastward, preceded by a rapid fall in pressure over the area dominated by the high, preventing the cold wave from extending farther.

Live-stock interests were advised of cold-wave warnings and severe conditions.

Frost warnings were issued for the northern portion of the district early in the month but by the close of the month were being issued only for the southern portions of Louisiana and east Texas. Warnings of freezing temperature were issued when indicated. Most of the warnings of frost or freezing temperature were verified. Frost warnings were issued on the 1st, 4th, 10th, 12th, 13th, 14th, 29th, and 30th.—*R. A. Dyke.*

Denver (Colo.) Forecast District.—The snowfall was unusually heavy for November over the northern half of the district, and heavy rains occurred in Arizona during the latter part of the month, causing remarkably high water in the Gila River. Several cold waves occurred; they formed quickly and developed intense cold along the middle eastern Rocky Mountain slope, while in southwestern Colorado and adjacent region the coming of the cold was belated.

Among the important warnings, which were fully verified as a rule, were the live-stock warnings issued on the morning of the 8th for eastern Colorado, the cold-wave warnings issued on the morning of the 11th for eastern Colorado, and the cold-wave warnings of the 26th for south and west Colorado and extreme eastern New Mexico, extended on the morning of the 27th over southwest Colorado, northwest New Mexico, north-central and northeast Arizona, and southeast Utah. On the morning of the 28th a warning was issued for freezing temperature in western and southern Arizona. This warning was fully verified. Several local cold waves occurred for which the forecast was confined to "colder" without the designation of "cold wave."—*Frederick H. Brandenburg.*

San Francisco (Calif.) Forecast District.—The pressure distribution prevailing over this district during November was unfavorable for precipitation except in western Washington. The pressure continued high, or comparatively high, over California and the Plateau region during the greater portion of the month, and the storms moving southeast from the north Pacific passed inland through northern British Columbia with an occasional depression moving southeastward over Alberta. This type of pressure distribution is not uncommon in September and October, but seldom prevails in November. It is one that causes fair and pleasant weather with warm days and cool nights in California and the Plateau region.

During the first week the storm movement was sufficiently far south to give precipitation over the northern portion of this district, but from the 8th to the 28th, the storm passage was farther north and very little precipitation occurred except in western Washington. On the 25th an area of low pressure developed over the southern Plateau, increased rapidly in intensity, gave rain in southern California on the 26th and 27th, and, in conjunction with a storm appearing over British Columbia on the 28th, caused light but general precipitation in other sections of this district until the close of the month.

Frosts occurred frequently in the interior of California, but were not of sufficient severity to cause material damage. Frost warnings were issued for the interior of California on the 9th to 14th, inclusive, and on the 27th and 28th, and in southern California on the 29th and 30th.

Storm warnings were ordered at the mouth of the Columbia River and Washington stations on the 1st, 3d, 6th, and 14th, from San Francisco to Eureka on the 26th, and from Port Harford to San Diego on the 27th. On the 26th and 27th fresh to whole northerly gales prevailed over northern California, knocking some oranges off the trees and wrecking a few small fishing boats in Monterey Bay. The winds during this storm attained a very high velocity, but the timely warnings undoubtedly prevented serious damage to shipping.—*G. H. Willson.*

RIVERS AND FLOODS, NOVEMBER, 1919.

ALFRED J. HENRY, Meteorologist in charge.

[Dated Dec. 29, 1919.]

Flood producing rains fell throughout the Ohio Valley and thence southwestward to Louisiana and northeast Texas on the last few days of October and again on November 1. Small floods occurred in the upper Trinity, the Sulphur, and Cypress Rivers of northeast Texas. At Liberty, Tex., on the Lower Trinity, the river was in flood the entire month, possibly by reason of the small slope between that point and the waters of Trinity Bay. The Sabine River was also in flood during a portion of the month. There were also slight floods in the small streams of Arkansas, West Virginia, Ohio and Indiana during the first decade of the month.

On the 10th, 11th, and 12th a general rainstorm passed northeastward from the Gulf States to the Lake region over substantially the same districts as on the first of the month. The resulting floods were not serious although the rivers carried more water than usual for this time of the year. Wide spread rains fell on the 25th and 26th and again on the 28th and 29th causing moderate floods in the smaller rivers of Arkansas, northeast Texas, upper Ohio Valley and Kentucky. The Ohio itself did not reach flood stage during the month except in the stretch between Evansville, Ind., and Shawneetown, Ill. After remaining in flood for about a week, the river slowly declined.

The significance of the November floods lies in the fact that the flow of the Mississippi has been materially increased over the average for November. The lower river at this writing (Dec. 29) is but 1.6 feet below flood stage at Vicksburg, Miss., and 2.1 feet below at New Orleans. High water in the Memphis district is described in the paragraph below:

HIGH WATER IN THE MEMPHIS DISTRICT, NOVEMBER, 1919,

S. C. EMERY, METEOROLOGIST.

The river stages in the Memphis district during November, 1919, were the highest on record for that month, the maximum stage at Memphis 30.1 feet, exceeded the previous high November stage of 1906, by 0.8 foot. The rise at Memphis began on September 24th, continued throughout the month of October, and reached its maximum 30.1 feet, on November 13 at Helena, Ark., the rise followed closely the Memphis gage, and reached its maximum 37.6 on November 16. While the Mississippi River nowhere reached the flood stage, there was a considerable portion of the low, unprotected land on both sides of the river considerably flooded, making it impossible to gather cotton and corn that was still in the fields, owing to the continued rains throughout October delaying such work. Much of these crops were more or less damaged and some even destroyed by being exposed to the rains and high winds. Also work on levee construction and other river improvement was entirely suspended throughout the month and contractors were forced to move their plants to high ground back of the levee. This caused a severe loss both to the contractor and employees, but the amount of this loss can not well be estimated. The rise in the St. Francis River began early October and continued steadily through November, reaching the flood stage 17.1 feet on the 30th of the month, remaining at that stage but two days. The flooding of this river and the surrounding country was due directly to unusually heavy local rains from the 25th to 29th of November. Crops still in the fields were much damaged and as water is still present on many farms a still further damage is expected.

Daily rains, 1st to 4th, inclusive, in Washington and Oregon caused the streams of those States to pass above flood stage on the 4th. The greatest loss sustained was to logs which broke from their moorings in the various streams and passed down stream beyond recovery. Railroad traffic was only slightly interrupted.

LOSS BY FLOOD—NOVEMBER, 1919.

The loss of corn that had not been gathered was heavy as in the preceding month. The total loss in the lower Ohio-Evansville, Mo., district, is estimated at $3,000,000. Heavy rains in Arizona on the 26th and 27th caused a sharp rise in the Hassayampa, Augua Fria, Verde and Salt Rivers on the 27th. Damages to bridges and approaches thereto in Arizona by this rise is placed at $142,000.

River.	Bridges, highways, etc.	Crops.		Live stock	Suspension of business.	Value of warnings.
		Matured.	Prospective.			
Trinity, (Tex.)	$32,000	$53,000	$19,500	$2,500	$2,500	$77,000
Black (Ark.)		150,000				
Petit Jean (Ark.)		12,000				
Ohio (Cairo dist.)		140,000				140,000
Duck (Tenn.)		300,000				
Pearl (La.)					5,000	2,000
White (Ind.)	100,000	300,000	250,000			
Total	132,000	955,000	269,500	2,500	7,500	219,000

TABLE I.—*Flood stages in the Atlantic, east Gulf, west Gulf, and Pacific drainage areas during month of November, 1919.*

Drainage, river, and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Atlantic drainage:					
Delaware, East branch, Fish's Eddy, N. Y.	*Feet.* 10	27	27	*Feet.* 10.8	27
East Gulf drainage:					
Chickasawhay, Shubuta, Miss	27	12	12	27.7	12
West Pearl, Pearl River, La	13	16	18	13.5	17
West Gulf drainage:					
Trinity—					
Fort Worth, Tex	20	(**)	1	24.8	1
Dallas, Tex	25	(**)	5	35.5	3
Do	25	29	(*)	34.2	30
Trinidad, Tex	28	(**)	17	38.0	†31 1
Liberty, Tex	25	(**)	(*)	28.2	30
Pacific drainage:					
Clackamas, South Fork, Oreg	12	4	4	14.0	4
Willamette—					
Eugene, Oreg	10	4	5	11.5	4
Oregon City, Oreg	10	6	7	10.8	6
Santiam, Jefferson, Oreg	10	4	5	15.0	4
Mississippi drainage, Ohio basin:					
Kiskiminetas, Saltsburg, Pa	8	27	27	9	27
Monongahela—					
Greensboro, Pa	20	26	27	22.1	26
Lock No. 4, Pa	31	27	27	32.9	27
Little Kanawha, Glenville, W. Va	22	2	2	22.8	2
Hocking, Athens, Ohio	17	27	28	19.1	28
Scioto, Circleville, Ohio	7	2	3	8.5	3
	7	27	28	9.3	28
Licking, Falmouth, Ky	28	27	27	28.5	27
Ohio—					
Evansville, Ind	35	6	11	38.2	8
Henderson, Ky	33	6	11	35.8	9
Mount Vernon, Ind	35	7	12	37.4	9, 10
Shawneetown, Ill	35	7	13	38.8	10, 11
Green—					
Lock No. 6, Brownsville, Ky	30	29	(*)	30.1	30
Lock No. 4, Woodbury, Ky	33	2	5	37.0	4
Do	33	28	(*)	39.8	30
Lock No. 2, Rumsey, Ky	34	6	9	35.3	8
Do	34	30	(*)	34.3	30
Wabash—					
Mount Carmel, Ill	15	(**)	12	20.8	7
Lafayette, Ind	11			15.0	2
White, Decker, Ind	18			21.1	7, 8
Mississippi drainage, northern and western tributaries:					
Wisconsin, Knowlton, Wis	12	12	12	12.6	12
Osage, Tuscumbia, Mo	25	(**)	3	33.8	†30

* Continued into December. ** Continued from October. † October.

TABLE I.—*Flood stages in the Mississippi drainage, Ohio Basin, during November, 1919*—Continued.

Drainage, river, and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Mississippi drainage, northern and western tributaries—Continued.	*Feet.*			*Feet.*	
Meramec—					
Pacific, Mo	11	(**)	4	16.6	3
Glencoe, Mo	15	(**)	4	26.5	†30
Valley Park, Mo	14	(**)	4	30.7	†30
Bourbeuse, Union, Mo	10	2	3	13.5	2
St. Francis, Marked Tree, Ark	17	30	30	17.1	30
Red, Alexandria, La	36	10	12	36.1	11,12
Ouachita—					
Arkadelphia, Ark	18	11	11	18.0	11
Camden, Ark	30	14	18	33.2	16
Petit Jean, Danville, Ark	20	2	4	22.1	3
Black—					
Black Rock, Ark	14	11	17	18.5	12
Do	14	27	(*)	17.0	30
Cache, Jelks, Ark	9	26	(*)	9.7	30
Sulphur—					
Finlay, Tex	24	(**)	3	28.6	†27
Do	24	11	16	25.4	11
Ringo Crossing, Tex	20	3	5	21.3	3,4
Do	20	11	13	21.3	11
Do	20	30	(*)	21.2	30
Cypress, Jefferson, Tex	18	13	17	22.5	14

* Continued into October. ** Continued from December. † October.

MEAN LAKE LEVELS DURING NOVEMBER, 1919.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Dec. 5, 1919.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during November, 1919:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.51	580.43	572.24	246.11
Above or below—				
Mean stage of October, 1919	+0.04	−0.20	−0.26	−0.24
Mean stage of November, 1918	−0.01	−0.67	+0.11	+0.11
Average stage for November, last 10 years	+0.01	+0.17	+0.43	+0.56
Highest recorded November stage	−1.00	−2.49	−1.43	−1.71
Lowest recorded November stage	+1.01	+1.25	+1.54	+2.70
Average relation to the November level to:				
October level		−0.2	−0.3	−0.2
December level		+0.2	+0.3	+0.2

* Lake St. Clair's level: In November, —— feet.

EFFECT OF WEATHER ON CROPS, NOVEMBER, 1919.

By J. B. KINCER, Acting Chief of Division.

Farm work.—Frequent rains in central and southwestern States seriously interrupted farm work during the first week of November, and the cold, snowy weather in the Northwest was unfavorable, while transportation was hindered by snow in some central districts. The weather was more favorable for field work, however, in the eastern States. The second decade and the first half of the third were more favorable for field work in the interior, resulting in the improved condition of roads and the drying out of fields. There was a return of weather unfavorable for field work during the last few days of the month in central and northwestern States, where there was an almost entire suspension of outdoor operations, as a result of snow and cold weather; more favorable weather conditions prevailed in the South during this period.

Winter grains.—Rain or snow during the first decade of the month was beneficial to winter grains in Rocky Mountain districts and the far Northwest and these crops made satisfactory advance in nearly all other sections of the country. It was too wet for seeding, however, in some sections, particularly in the lower Great Plains and the southern drainage area of the Ohio River, while it was too dry for best results in California and some adjoining localities. The continued rains and wet soil were unfavorable for oat seeding in the west Gulf region, but at the same time the rains in the eastern portion of the winter oat belt were favorable. Weather conditions improved in the southern Great Plains and the Ohio Valley during the second decade, when drier weather favored late seeding which had been greatly delayed. The latter part of the month was favorable for winter grains in nearly all sections of the country, except for too much rain in parts of the Ohio Valley and Tennessee and also in the Southwest. At the close of the month protection was afforded by a good snow cover in the central and northern Great Plains, the upper Missippi Valley and the far Northwest. Only a small acreage of winter grains was sown in the west Gulf region and a considerable reduction in acreage resulted in some central districts on account of inability to seed in the wet soil. There was much complaint of fly in the early sown wheat in many sections.

Corn and cotton.—Corn husking was delayed during the first half of the month in many central and southwestern States by frequent rains and considerable damage was done to grain in shock. Better progress was made in this work the latter part, however, under more favorable weather conditions, although the last few days of the month were unfavorable in the northern and western States.

Cotton picking was interrupted by rain during the first 10 days of the month from the Mississippi Valley westward and considerable damage was done to ungathered cotton in the fields, but harvest made satisfactory progress in the eastern districts. By the 10th of the month the early crop had been mostly picked in the Carolinas and picking was practically completed in Georgia. After the first decade the cessation of rains in the western portion of the belt permitted better progress in picking in that section. The freeze in the northern and central portions of the cotton growing area on the 12th to 14th expedited opening, and bolls came out rapidly thereafter. Weather favorable for picking continued in the western and northwestern portions of the belt until the last week in the month when rains again interfered with this work. At the close of the month cotton was nearly all harvested in the eastern portion of the belt, but considerable remained to be picked in Arkansas, northern and northwestern Texas, and in Oklahoma.

Pastures, truck, and fruit.—Pastures were favorably affected by the weather of the month in nearly all central and eastern districts, but in the northern Plains and in northwestern districts the range was mostly snow-covered, preventing grazing and causing suffering of stock, with considerable losses in some sections, particularly in Montana. It was too dry for the range in California and the lack of moisture unfavorably affected pastures in portions of the Southeast also.

Winter truck was somewhat unfavorably affected in the central Gulf region by the unseasonably high temperatures early in the month, and it was much too wet in the lower Mississippi Valley region, but at the same time the rains benefited sugar cane in Florida. The freeze in the central and northern portions of the Gulf States near the middle of the month did considerable damage to gardens and tender truck crops in those localities, but the latter half of the month was generally favorable for truck in the Southern States, except for a lack of moisture in some immediate South Atlantic coast districts.

Rains early in the month benefited citrus fruits in Florida, but under the influence of warm weather they colored slowly and considerable dropping was reported. The cooler weather later in the month was beneficial, but complaints of dropping continued. The weather was generally favorable for citrus fruits in California, except that some damage was done to oranges, lemons, and olives by high winds. The quality of lemons was reported as excellent in that State, and the picking of lemons and oranges was becoming more general at the end of the month.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, November, 1919.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	57.3	+ 3.9	2 stations	87	1†	Riverton	21	14	4.49	+1.59	Riverton	9.05	Thomasville	2.13
Arizona	49.0	− 1.8	Mohawk	89	16	Moccasin	−14	29	3.25	+2.07	Sycamore Ranger Station.	7.76	Yuma	0.28
Arkansas	51.4	− 0.3	Camden	86	1	3 stations	14	13	6.27	+2.77	Wynne	11.97	Springbank	2.42
California	50.9	− 2.0	Azusa	93	16	Fordyce Dam	−10	27	0.90	−1.91	Sonora	8.33	11 stations	0.00
Colorado	31.8	− 3.5	Crawford	82	21	Fry's Ranch	−20	28	1.88	+1.15	Palisade Lake	7.12	Colorado Springs	0.16
Florida	69.0	+ 4.0	4 stations	92	1†	Quincy	34	15†	3.35	+1.43	Bonifay	11.92	Tallahassee	0.81
Georgia	58.7	+ 4.2	2 stations	91	1	Ramhurst	20	14	1.95	−0.66	Dahlonega	4.90	2 stations	0.38
Hawaii (October)	74.1	+ 0.5	Mahukona	97	7	Volcano Observatory	50	30	4.82	−0.01	Waiakamoe	15.51	3 stations	0.00
Idaho	32.0	− 3.3	Salmon	70	4	2 stations	−30	27	1.97	−0.15	Boulder Mine	5.52	Spencer	0.04
Illinois	40.3	− 1.5	Mount Carmel	72	9	4 stations	10	13†	3.38	+0.86	Shawneetown	7.70	Antioch	1.73
Indiana	41.7	− 0.4	2 stations	74	9	Marengo	11	14	3.70	+0.47	Rome	6.94	Goshen	1.13
Iowa	33.6	− 1.4	3 stations	68	1†	Alton	−12	13	3.40	+1.89	Indianola	6.22	Storm Lake	1 97
Kansas	39.8	− 4.3	2 stations	81	5	Alton	− 6	30	2.02	+0.87	Eskridge	3.45	Kismet (near)	0.48
Kentucky	47.4	+ 1.3	2 stations	78	9	2 stations	16	14	7.31	+3.96	Brownsville	10.63	Alpha	3.25
Louisiana	62.6	+ 3.8	Schriever	90	7	2 stations	23	14	7.34	+3.67	Houma	17.53	Grand Coteau	1.80
Maryland-Delaware	45.7	+ 1.2	Salisbury, Md	81	1	Oakland, Md	11	25	3.30	+0.83	Friendsville, Md	4.72	Western Port, Md	1.67
Michigan	34.0	− 1.7	Monroe	69	1	Humboldt	−15	28	2.90	+0.42	Houghton	9.21	Ceresco	0.52
Minnesota	23.1	− 6.0	Luverne	63	9	Argyle	−31	26	2.20	+1.14	Cloquet	4.29	Angus	0.78
Mississippi	58.2	+ 3.1	2 stations	89	1	3 stations	21	13†	8.83	+5.58	Greenwood	14.63	Pascagoula	4.84
Missouri	42.2	− 2.2	Hollister	78	10	Maryville	2	30	3.62	+1.40	Doniphan	7.96	Nevada	1.17
Montana	25.2	− 7.3	Roundup	70	15	Bowen	−34	27	1.06	0.00	Trout Creek	3.91	Cut Bank	0.03
Nebraska	31.1	− 5.4	Weeping Water	75	18	2 stations	−14	11†	2.57	+1.85	West Point	4.66	Bridgeport	0.88
Nevada	37.5	− 2.3	Las Vegas	82	1	San Jacinto	−22	27	0.46	−0.23	Owyhee	1.43	3 stations	0.00
New England	37.7	+ 0.6	Waterbury, Conn	75	1	Houlton, Me	− 1	29	4.56	+1.22	Westboro, Mass	6.92	Burlington, Vt	2.10
New Jersey	43.7	+ 0.7	2 stations	76	1	Culvers Lake	10	31	3.74	+0.35	Culvers Lake	6.18	Vineland	1.98
New Mexico	41.7	− 1.0	3 stations	84	3†	Blackrock	− 9	29	1.05	+0.32	Cloverdale	3.44	Fruitland	0.10
New York	37.7	+ 0.2	Flushing	75	1	Gabriels	2	27	3.21	+0.41	West Point	6.19	Romulus	0.74
North Carolina	51.3	+ 2.2	Smithfield	89	1	3 stations	15	21†	1.32	−1.43	Highlands	8.58	Pinehurst	T.
North Dakota	15.5	−11.1	2 stations	50	22†	Howard	−36	27	1.18	+0.60	Larimore	3.40	Donnybrook	0.13
Ohio	41.2	+ 0.1	Hamilton	75	1	Milligan	11	15	4.02	+1.09	Green	7.40	2 stations	1.19
Oklahoma	46.5	− 4.0	Snyder	84	7	Hurley	1	27	2.97	+0.80	Broken Bow	5.78	Hooker	0.46
Oregon	39.9	− 1.9	McKinley	73	16	Blitzen	−18	26†	4.60	+0.14	Welches (near)	17.62	Burns	0.04
Pennsylvania	41.2	+ 0.5	Ephrata	76	1	2 stations	11	16	5.35	+1.47	Somerset	8.45	Erie	1.84
Porto Rico														
South Carolina	56.6	+ 2.8	Garnett	92	2	Bowman	20	15†	0.86	−1.38	Landrum	3.96	2 stations	0.00
South Dakota	25.4	− 7.0	Wagner	72	2	La Delle	−20	13	1.51	+1.22	Colome	4.03	Eureka	0.22
Tennessee	50.4	+ 1.8	Copperhill	82	1	Crossville	14	14	6.36	+2.83	Perryville	12.41	Greeneville	1.16
Texas	56.8	− 0.4	3 stations	93	3†	Lieb	2	29	2.59	+0.29	Gatesville	9.30	Hebbronville	0.00
Utah	34.9	− 2.4	Nephi (near)	87	23	2 stations	−14	18†	1.35	+0.35	Lockerby	4.55	Midlake	T.
Virginia	47.8	+ 1.2	Cape Henry	86	1	Burkes Garden	10	14	2.04	−0.34	Elk Knob	4.90	Cape Henry	0.08
Washington	38.4	− 1.8	Lowden	72	16	Anatone	− 5	27	4.49	−0.87	Forks	22.11	2 stations	0.49
West Virginia	44.5	+ 1.5	Charleston	80	1	Marlinton	10	14†	4.51	+2.07	Smithfield	7.53	Upper Tract	0.85
Wisconsin	29.9	− 3.2	Marinette	69	18	2 stations	−10	26	2.96	+1.13	Rest Lake	4.77	Ripon	1.16
Wyoming	25.4	− 6.5	Painter	74	23	Soda Butte	−32	27	1.05	+0.50	Echeta	3.41	Powell	T.

*For explanation of the following tables and charts, see this REVIEW, January, 1919, pp. 52-53.

†Other dates also.

TABLE I.—*Climatological data for Weather Bureau stations, November, 1919.*

Districts and stations.	Elevation of instruments: Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Departure from normal.	Days with 0.01 inch or more.	Wind: Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
New England.							**40.1**	**+1.1**										**78**	**3.92**	**+0.4**										**6.9**		
Eastport	76	67	85	29.96	30.04	+ .03	37.6	+ 0.8	56	30	43	19	28	32	23	35	31	79	4.10	0.0	16	10,269	nw.	72	ne.	5	4	6	20	7.7	1.9	0.0
Greenville, Me	1,070	6		28.86	30.06		30.6		49	22	37	7	29	24	26	......	......	......	3.58	......	14	......		......	......	......	5	1	24	......	12.9	......
Portland, Me	103	82	117	29.95	30.08	+ .04	38.4	+ 0.8	63	30	45	19	21	32	26	35	31	77	4.71	+ 0.9	15	7,396	n.	38	s.	30	9	4	17	6.4	2.7	0.0
Concord	288	70	79	29.75	30.07	+ .01	37.7	+ 0.9	62	30	45	18	16	30	31				3.98	+ 0.6	13	4,146	nw.	32	nw.	19	9	5	16	6.7	7.0	0.0
Burlington	404	11	48	29.62	30.07	+ .02	34.6	+ 0.9	56	12	41	12	28	28	26				2.10	− 0.5	15	10,367	s.	52	s.	11	2	4	24	8.4	7.4	T.
Northfield	876	12	60	29.11	30.08	+ .03	33.7	+ 1.9	64	1	41	10	21	26	41	30	26	78	2.36	− 0.2	16	5,904	n.	35	sw.	30	2	6	22	8.2	18.3	T.
Boston	125	115	188	29.92	30.06	+ .01	42.8	+ 1.6	65	30	50	25	21	36	29	39	35	78	5.36	+ 1.3	13	8,059	sw.	36	nw.	20	7	7	16	6.7	0.2	0.0
Nantucket	12	14	90	30.03	30.04	− .01	44.6	− 0.6	61	13	50	27	21	39	22	42	39	83	4.20	+ 0.9	15	13,006	ne.	54	ne.	5	5	6	19	7.1	0.0	0.0
Block Island	26	11	46	30.03	30.06	.00	44.8	− 0.5	66	1	50	26	20	39	23	42	40	85	3.54	− 0.3	11	14,713	nw.	69	nw.	5	7	6	17	6.7	0.0	0.0
Providence	160	215	251	29.89	30.07	.00	42.1	+ 1.7	65	1	50	23	21	35	28	38	34	77	3.79	− 0.1	13	9,992	nw.	55	w.	30	8	10	12	5.9	T.	0.0
Hartford	159	122	140	29.91	30.09	+ .01	42.0	+ 2.5	71	1	50	22	20	34	30	37	32	72	4.69	+ 0.9	11	6,174	n.	42	sw.	30	6	10	14	6.7	T.	0.0
New Haven	106	74	153	29.97	30.09	+ .02	43.0	+ 1.7	71	1	50	22	20	36	27	39	34	72	4.30	+ 0.7	11	7,931	n.	46	nw.	5	10	8	12	5.7	T.	0.0
Middle Atlantic States.							**45.8**	**+1.5**										**74**	**2.72**	**−0.2**										**5.7**		
Albany	97	102	115	29.98	30.09	+ .01	39.8	+ 1.4	68	1	47	21	20	33	27	35	31	74	3.30	+ 0.5	12	6,497	s.	30	s.	11	8	11	11	6.3	T.	0.0
Binghamton	871	10	84	29.13	30.09	.00	39.3	+ 0.9	62	1	47	15	21	32	36				3.48	+ 1.2	13	5,382	nw.	40	sw.	30	6	5	19	7.5	3.1	0.0
New York	314	414	454	29.74	30.09	.00	44.4	+ 0.4	70	1	52	26	20	37	30	40	34	70	3.33	− 0.1	13	14,254	nw.	61	nw.	6	7	9	14	6.5	T.	0.0
Harrisburg	374	94	104	29.72	30.13	+ .02	44.0	+ 2.3	67	1	51	28	25	37	24	38	33	71	3.56	+ 1.2	12	5,200	e.	31	w.	30	9	9	12	5.6	T.	0.0
Philadelphia	117	123	190	29.99	30.12	+ .02	46.8	+ 1.9	72	1	54	29	20	39	26	41	36	72	2.80	− 0.3	11	7,602	nw.	34	nw.	5	9	9	12	5.7	T.	0.0
Reading	325	81	98	29.76	30.12		44.0		68	1	52	26	16	36	28	39	34	72	4.57	+ 1.4	11	5,552	se.	30	nw.	5	10	8	12	5.9	T.	0.0
Scranton	805	111	119	29.22	30.10	+ .01	41.0	+ 1.9	65	1	48	22	21	34	28	36	33	77	2.76	+ 0.5	10	5,859	nw.	46	sw.	30	3	9	18	7.4	T.	0.0
Atlantic City	52	37	48	30.05	30.10	.00	47.2	+ 1.7	74	1	54	28	20	40	28	43	39	74	3.27	0.0	11	5,828	nw.	27	s.	30	13	5	12	5.1	0.0	0.0
Cape May	18	13	49	30.12	30.14	+ .04	47.8	+ 0.4	72	1	54	29	21	41	23	44	40	78	2.80	− 0.4	10	7,559	nw.	36	nw.	5	11	5	14	5.5	0.0	0.0
Sandy Hook	22	10	57	30.08	30.10	......	45.7	......	69	1	51	29	21	40	26	42	39	81	2.98	......	12	13,679	nw.	64	nw.	5	9	9	12	5.8	0.0	0.0
Trenton	190	159	183	29.89	30.10	......	43.8	......	70	1	52	25	21	36	29	40	36	78	3.10	− 0.3	11	8,707	n.	45	sw.	30	9	7	14	5.8	T.	0.0
Baltimore	123	100	113	29.99	30.12	+ .01	47.4	+ 1.7	73	1	55	31	14	40	27	42	38	74	3.10	+ 0.2	12	4,283	sw.	26	nw.	6	11	11	8	5.0	0.0	0.0
Washington	112	62	85	30.00	30.13	+ .01	46.8	+ 1.8	73	1	56	28	16	38	29	41	36	74	2.32	− 0.4	13	4,827	nw.	36	nw.	19	11	7	12	5.4	T.	0.0
Lynchburg	681	153	188	29.38	30.14	+ .01	48.2	+ 2.1	79	1	58	24	21	38	38	42	37	74	2.48	− 0.3	9	4,413	e.	34	nw.	30	14	3	13	5.3	0.0	0.0
Norfolk	91	170	205	30.03	30.13	+ .02	53.0	+ 1.8	81	1	61	33	20	45	31	46	41	71	0.20	− 2.5	5	9,521	n.	42	nw.	24	13	9	8	4.3	0.0	0.0
Richmond	144	11	52	29.98	30.14	+ .02	48.8	0.0	82	1	60	27	21	38	37	42	37	71	1.31	− 1.1	9	5,208	ne.	32	sw.	30	15	4	11	4.6	0.0	0.0
Wytheville	2,304	49	55	27.70	30.12	− .01	46.2	+ 3.2	74	1	56	22	20	37	36	39	34	73	1.06	− 2.0	8	4,781	w.	33	nw.	30	14	5	11	4.5	0.0	0.0
South Atlantic States.							**57.4**	**+3.3**										**73**	**0.59**	**−2.2**										**5.0**		
Asheville	2,255	70	84	27.76	30.16	+ .02	48.4	+ 3.3	73	1	58	22	14	39	36	42	37	73	0.54	− 2.8	6	6,280	se.	31	se.	26	12	8	10	4.8	0.0	0.0
Charlotte	779	153	161	29.28	30.13	.00	52.9	+ 2.5	79	1	62	28	20	44	30	45	39	66	1.02	− 1.8	4	3,338	ne.	24	s.	26	10	7	13	5.4	0.0	0.0
Hatteras	11	12	50	30.10	30.11	.00	56.6	− 0.1	78	1	62	37	20	51	25	52	49	79	0.25	− 4.4	7	10,548	n.	39	w.	2	5	14	11	6.0	0.0	0.0
Manteo	12	5	42																													
Raleigh	376	103	110	29.72	30.14	+ .01	52.1	+ 1.9	81	1	62	28	20	42	30	46	41	72	1.44	− 0.9	5	5,275	ne.	28	sw.	30	13	3	14	5.4	0.0	0.0
Wilmington	78	81	91	30.04	30.12	.00	56.8	+ 2.7	82	1	67	30	20	47	26	50	46	75	0.07	− 2.4	4	5,387	ne.	25	sw.	30	16	8	6	4.2	0.0	0.0
Charleston	48	11	92	30.05	30.10	− .02	62.2	+ 4.1	83	1	70	41	20	55	25	55	50	73	0.23	− 2.6	5	7,948	ne.	27	ne.	14	12	9	9	4.8	0.0	0.0
Columbia, S. C.	351	41	57	29.74	30.13	+ .01	57.4	+ 3.6	85	1	67	29	15	47	34	49	42	65	0.10	− 2.1	3	4,718	ne.	31	s.	29	12	12	6	4.7	0.0	0.0
Greenville, S. C.	1,013	113	122	29.01	30.11	......	53.4	......	77	1	62	30	14	45	32	46	40	68	3.09	......	7	5,652	ne.	37	w.	1	12	7	11	4.8	0.0	0.0
Augusta	180	62	77	29.91	30.10	− .03	58.8	+ 4.9	86	1	70	32	21	48	34	51	47	74	0.43	− 2.5	3	3,583	nw.	23	sw.	26	13	8	9	4.4	0.0	0.0
Savannah	65	150	194	30.03	30.10	− .02	62.6	+ 5.1	84	1	71	39	21	55	27	55	51	75	0.75	− 1.6	4	8,052	ne.	44	w.	1	10	7	13	5.6	0.0	0.0
Jacksonville	43	200	245	30.02	30.07	− .03	66.6	+ 5.3	85	1	73	46	15	60	21	60	57	79	1.06	− 1.1	6	9,114	ne.	31	ne.	14	13	7	10	5.0	0.0	0.0
Florida Peninsula.							**73.5**	**+2.5**										**75**	**3.73**	**+1.5**										**4.6**		
Key West	22	10	64	29.99	30.01	− .01	76.0	+ 1.7	85	1	80	64	20	72	15	69	66	76	5.23	+ 2.9	7	7,379	ne.	41	w.	6	17	9	4	3.5	0.0	0.0
Miami	25	71	79	30.00	30.03	......	73.4	+ 1.4	85	2	79	54	19	68	23	67	64	76	3.48	+ 0.9	11	5,953	e.	32	nw.	18	9	10	11	5.8	0.0	0.0
Sand Key	23	39	72	29.95	29.98	− .02	75.6	......	84	30	78	67	18	73	11	69	66	72	......	......	......	11,420	ne.	46	......	6	15	12	3	3.7	0.0	0.0
Tampa	38	79	92	30.01	30.05	− .03	71.2	+ 4.4	86	1	79	55	22	63	22	63	60	77	2.47	+ 0.8	7	5,058	ne.	24	nw.	4	9	12	9	5.4	0.0	0.0
East Gulf States.							**59.9**	**+4.4**										**77**	**4.26**	**+0.7**										**5.3**		
Atlanta	1,174	190	216	28.87	30.12	− .01	54.7	+ 2.8	77	1	63	32	14	46	24	48	43	72	2.92	− 0.5	6	8,235	nw.	33	nw.	30	14	4	12	5.0	0.0	0.0
Macon	370	78	87	29.70	30.10	− .03	58.1	+ 6.3	83	1	69	31	15	47	36	50	46	73	0.64	− 2.5	4	4,195	n.	28	sw.	1	15	4	11	4.4	0.0	0.0
Thomasville	273	49	58	29.78	30.08	− .04	64.2	+ 5.7	84	1	74	38	15	55	27	56	55	74	3.40	+ 0.8	6	3,366	ne.	19	sw.	29	10	10	10	5.4	0.0	0.0
Pensacola	56	140	182	30.01	30.07	− .04	64.5	+ 4.9	80	1	71	37	14	58	26	60	57	79	2.68	− 1.1	8	10,995	ne.	49	se.	9	11	4	15	5.9	0.0	0.0
Anniston	741	9	57	29.32	30.13	+ .01	54.5	+ 2.6	79	1	66	26	15	43	39	......	......	......	3.98	+ 0.6	7	3,931	nw.	26	w.	29	17	2	11	4.7	0.0	0.0
Birmingham	700	11	48	29.35	30.13	+ .01	56.0	+ 1.9	75	1	66	28	14	46	35	48	44	72	4.01	+ 0.6	8	4,857	n.	39	s.	29	13	6	11	5.1	0.0	0.0
Mobile	57	125	161	30.01	30.07	− .04	63.8	+ 6.3	81	7	72	35	14	56	27	58	55	80	4.58	+ 0.8	7	7,738	n.	39	se.	10	7	10	13	6.0	0.0	0.0
Montgomery	223	100	112	29.86	30.11	− .01	59.2	+ 3.5	82	1	69	35	14	50	29	52	48	75	3.07	− 0.1	6	4,657	e.	30	sw.	26	13	6	11	5.0	0.0	0.0
Corinth	469	6	......	......	......	......	52.9	......	76	6	65	22	14	41	40	......	......	......	8.80	......	12	......	n.	......	......	......	11	8	11	......	0.0	0.0
Jackson	304	5	......	......	......	......	59.3	......	83	6	71	27	14	47	39	......	......	......	7.55	......	7	......	ne.	......	......	......	18	6	6	......	0.0	0.0
Meridian	375	85	93	29.69	30.09	− .03	58.2	+ 5.0	77	8	68	30	14	48	31	52	48	81	6.62	+ 2.5	6	3,954	ne.	31	w.	29	11	10	9	4.9	0.0	0.0
Vicksburg	247	65	74	29.79	30.08	− .04	59.0	+ 3.1	78	6	68	29	14	50	29	53	50	81	7.66	+ 3.5	8	4,720	se.	30	nw.	26	8	11	11	5.4	0.0	0.0
New Orleans	53	76	84	30.00	30.06	− .04	66.4	+ 5.8	81	8	73	41	14	60	26	62	60	86	7.29	+ 3.5	9	5,386	ne.	30	nw.	29	8	9	13	6.0	0.0	0.0
West Gulf States.							**57.4**	**+1.0**										**77**	**3.83**	**+0.8**										**5.0**		
Shreveport	249	77	93	29.82	30.10	− .01	57.8	+ 2.5	79	9	67	32	14	49	29	52	48	79	4.68	+ 0.6	8	4,562	n.	37	w.	29	15	6	9	4.5	0.0	0.0
Bentonville	1,303	11	44	28.70	30.08	− .03	46.2	− 0.5	72	23	57	16	13	35	34	......	......	......	5.16	+ 2.2	10	3,891	sw.	19	sw.	29	14	4	12	4.9	T.	0.0
Fort Smith	457	79	94	29.60	30.09	− .02	50.0	+ 0.1	75	24	59	25	13	41	34	44	39	72	2.81	− 0.5	10	5,617	e.	37	w.	29	15	3	12	4.6	T.	0.0
Little Rock	357	139	147	29.71	30.10	− .02	52.8	+ 1.3	75	23	62	26	13	43	31	46	42	73	8.21	+ 3.6	10	5,603	e.	39	nw.	25	15	7	8	4.4	0.0	0.0
Brownsville	57	4	26	......	......	......	70.5	......	88	3	80	46	30	61	31	......	......	......	2.34	......	9	......	ne.	......	......	......	......	......	......	......	......	......
Corpus Christi	20	69	77	30.03	30.05	− .02	65.6	+ 2.5	84	7	73	42	13	58	22	61	59	81	0.27	− 2.1	4	7,179	n.	42	se.	9	7	7	16	6.5	0.0	0.0
Dallas	512	109	117	29.53	30.08	......	54.1	......	79	3	63	28	13	45	29	......	......	......	3.79	......	7	5,272	nw.	35	sw.	29	14	8	8	4.4	0.0	0.0
Fort Worth	670	106	114	29.34	30.06	− .04	53.6	− 1.5	80	3	63	26	13	44	30	48	44	75	3.32	+ 1.8	7	6,314	nw.	38	w.	29	15	5	10	4.8	0.0	0.0
Galveston	54	106	114	30.01	30.07	− .02	65.4	+ 2.5	82	9	71	43	14	60	25	61	58	80	1.97	− 2.0	10	7,544	n.	38	n.	10	8	12	10	5.3	0.0	0.0
Houston	138	111	121	29.91	30.06	......	63.4	+ 2.1	87	6	72	36	14	54	26	......	......	......	1.78	......	7	5,194	n.	32	nw.	9	10	10	10	5.2	0.0	0.0
Palestine	510	64	72	29.54	30.08	− .03	57.5	+ 0.6	80	6	67	31	13	48	28	51	47	78	7.10	+ 3.5	8	4,581	ne.	30	w.	29	16	3	11	4.5	0.0	0.0
Port Arthur	34	58	66	30.00	30.04	......	63.4	......	82	1	72	35	14	55	27	58	55	81	2.77	......	8	6,112	e.	43	nw.	26	10	7	13	5.8	0.0	0.0
San Antonio	701	119	132	29.33	30.06	− .02	60.8	+ 1.6	83	6	71	33	13	51	31	54	49	75	1.56	− 0.2	7	5,356	n.	38	nw.	25	11	6	13	5.2	0.0	0.0
Taylor	582	55	63	29.48	30.10	+ .02	57.8	+ 0.1	84	3	68	30	13	48	30	......	......	......	3.19	+ 0.6	8	5,325	n.	36	nw.	29	10	6	14	5.6	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, November, 1919*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 inch or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
Ohio Valley and Tennessee.	Ft.	Ft.	Ft.	In.	In.	In.	°F. 45.5	°F. + 0.9	°F.		°F.	°F.		°F.	°F.	°F.	°F.	% 75	In. 4.61	In. + 1.2		Miles.								0–10 5.6	In.	In.
Chattanooga	762	189	213	29.32	30.14	.00	52.3	+ 2.0	74	1	61	31	15	44	29	45	40	69	2.68	− 0.9	10	5,214	ne.	33	s.	29	13	6	11	4.9	0.0	0.0
Knoxville	996	102	111	29.05	30.12	− .01	51.0	+ 3.9	73	1	60	28	14	42	28	45	40	74	2.19	− 1.4	10	4,074	ne.	27	sw.	29	10	9	11	5.5	0.0	0.0
Memphis	399	76	97	29.71	30.14	+ .02	52.1	+ 0.7	72	1	61	28	13	44	29	47	42	74	7.75	+ 3.2	9	5,353	n.	48	sw.	29	17	3	10	4.1	0.0	0.0
Nashville	546	168	191	29.54	30.14	+ .02	49.7	+ 1.0	70	1	59	23	14	40	31	44	40	75	7.89	+ 4.0	10	6,381	ne.	55	se.	29	14	7	9	4.5	0.0	0.0
Lexington	989	193	230	29.04	30.13	+ .01	44.9	+ 0.2	69	9	53	21	13	37	27	....	....	....	8.50	+ 5.0	12	9,494	sw.	62	sw.	29	13	5	12	5.1	0.0	0.0
Louisville	525	219	255	29.54	30.13	+ .01	46.0	− 0.3	70	9	54	22	13	38	31	42	38	78	5.59	+ 1.4	8	8,729	n.	58	sw.	29	16	3	11	4.6	0.0	0.0
Evansville	431	139	175	29.65	30.13	+ .01	46.3	+ 1.0	71	9	54	23	13	38	33	42	37	74	3.73	− 0.4	8	7,953	sw.	67	sw.	29	11	8	11	5.3	0.0	0.0
Indianapolis	822	194	230	29.21	30.11	+ .01	41.6	0.0	64	9	50	20	13	34	31	37	33	76	3.27	− 0.2	10	9,681	s.	58	sw.	29	11	5	14	6.0	T.	0.0
Terre Haute	575	96	129	29.47	30.10	......	42.5	......	68	9	50	20	13	34	32	37	33	73	2.65	......	10	7,588	se.	48	w.	29	8	10	12	5.9	0.0	0.0
Cincinnati	628	11	51	29.43	30.13	+ .01	42.2	+ 2.6	65	9	51	20	13	34	33	38	34	76	3.65	+ 0.4	11	5,977	sw.	48	sw.	29	9	8	13	5.8	T.	0.0
Columbus	824	179	222	29.22	30.12	+ .01	40.6	− 0.8	61	1	48	21	13	33	30	37	33	77	4.23	+ 1.1	13	8,963	se.	52	s.	29	8	10	12	6.0	T.	0.0
Dayton	899	181	216	29.11	30.09	......	41.9	− 0.2	63	9	50	20	13	34	32	37	34	77	3.23	+ 0.3	11	8,372	sw.	56	sw.	29	11	8	11	5.6	T.	0.0
Pittsburgh	842	353	410	29.19	30.11	+ .01	42.6	− 0.3	63	29	50	23	14	35	27	38	33	72	3.82	+ 1.3	11	8,936	sw.	49	sw.	29	7	6	17	6.4	0.5	0.0
Elkins	1,947	41	50	28.04	30.15	+ .03	41.4	+ 1.8	65	9	52	17	14	31	41	36	33	80	3.25	+ 0.4	15	4,139	w.	34	sw.	26	8	5	17	6.9	3.0	0.0
Parkersburg	638	77	82	29.47	30.14	+ .02	44.8	+ 1.6	65	9	54	22	14	36	31	39	34	73	4.76	+ 1.9	11	4,243	sw.	26	se.	29	6	8	16	6.8	0.4	0.0
Lower Lake Region.							38.8	− 0.3										74	1.57	− 1.4										7.4		
Buffalo	767	247	280	29.22	30.07	+ .02	38.4	− 0.9	63	10	45	21	20	32	26	35	32	79	1.38	− 2.0	11	15,309	w.	82	sw.	30	0	11	19	8.4	2.9	0.4
Canton	448	10	61	29.56	30.05	......	34.2	+ 0.3	59	12	41	7	28	27	40	....	....	....	1.13	− 2.3	12	9,825	sw.	57	sw.	29	5	1	24	8.3	2.5	T.
Oswego	335	76	91	......	30.06	+ .01	38.6	− 0.5	63	1	45	19	28	32	27	....	....	....	1.70	− 1.7	9	9,926	s.	41	w.	30	0	7	23	....	0.6	0.0
Rochester	523	97	113	29.50	30.08	+ .03	38.8	+ 0.9	65	12	45	20	20	32	28	34	29	71	1.49	− 1.3	15	7,370	w.	42	w.	30	1	9	20	8.3	5.8	1.3
Syracuse	597	97	113	29.43	30.09	+ .03	38.2	− 0.5	65	1	45	16	20	31	32	....	....	....	2.00	− 0.7	15	9,406	s.	52	s.	29	0	13	17	7.8	7.1	T.
Erie	714	130	166	29.29	30.07	+ .01	40.2	− 0.9	63	1	46	23	30	34	23	36	30	68	1.84	− 1.8	13	12,872	sw.	54	sw.	30	2	6	22	8.0	6.6	1.5
Cleveland	762	190	201	29.26	30.10	+ .03	41.1	+ 0.7	62	1	47	23	14	23	35	36	31	70	1.31	− 1.4	11	11,515	sw.	60	w.	29	8	4	18	7.0	0.4	T.
Sandusky	629	62	103	29.39	30.09	+ .01	40.6	− 0.2	63	1	47	22	14	34	28	....	....	....	1.36	− 1.4	10	11,219	sw.	68	sw.	29	6	7	17	6.8	T.	0.0
Toledo	628	208	243	29.40	30.10	+ .03	39.5	− 0.2	61	1	46	21	30	32	27	35	31	76	1.60	− 1.0	11	12,276	sw.	82	sw.	29	10	6	14	6.2	0.5	T.
Fort Wayne	856	113	124	29.16	30.11	......	39.0	− 1.6	59	29	46	19	30	32	29	34	30	76	2.70	......	10	8,272	sw.	66	sw.	29	8	8	14	6.1	0.6	0.0
Detroit	730	218	245	29.29	30.09	+ .03	38.6	0.0	57	17	45	21	15	32	26	34	31	78	1.91	− 0.7	8	10,593	w.	87	sw.	29	4	7	19	7.0	0.4	T.
Upper Lake Region.							32.9	− 1.4										79	3.32	+ 0.9										7.5		
Alpena	609	13	92	29.36	30.04	+ .03	34.3	+ 0.6	55	10	40	15	27	29	26	31	28	81	2.63	+ 0.1	15	10,313	sw.	46	sw.	30	0	7	23	8.7	7.4	T.
Escanaba	612	54	60	29.34	30.03	.00	31.0	− 0.7	55	17	37	2	30	25	27	29	26	81	4.45	+ 2.2	14	8,178	nw	48	s.	10	5	11	14	6.7	12.4	7.0
Grand Haven	632	54	89	29.36	30.06	+ .02	36.6	− 1.4	58	10	42	17	27	31	32	34	31	80	2.77	+ 0.2	11	11,189	w.	56	sw.	29	1	6	23	8.2	0.9	0.4
Grand Rapids	707	70	87	29.28	30.07	+ .02	37.2	− 0.9	58	10	43	19	26	31	31	34	30	77	2.30	− 0.2	10	5,656	w.	30	sw.	29	0	9	21	8.4	3.5	3.0
Houghton	684	62	99	29.27	30.02	.00	28.7	− 2.8	58	10	34	5	28	23	28	....	....	....	9.21	+ 6.4	18	8,542	e.	42	w.	11	1	4	25	9.0	66.6	28.0
Lansing	878	11	62	29.11	30.07	......	35.7	− 1.1	57	29	43	15	15	28	32	32	29	82	2.44	0.0	12	6,063	w.	35	sw.	29	2	9	19	7.9	3.1	1.0
Ludington	637	60	66	29.34	30.05	......	35.2	......	58	10	41	13	20	29	25	33	30	80	3.10	......	14	10,362	w.	54	sw.	10	3	7	20	7.6	3.6	0.6
Marquette	734	77	111	29.22	30.04	+ .02	30.0	− 1.9	56	10	36	5	30	24	23	28	24	78	4.18	+ 1.4	18	6,411	nw.	38	s.	10	1	4	25	8.8	26.1	16.7
Port Huron	638	70	120	29.36	30.07	+ .02	37.0	+ 0.2	57	29	43	18	15	31	29	34	30	81	1.71	− 1.0	6	10,304	nw.	76	w.	29	5	6	19	7.1	0.4	T.
Saginaw	641	69	77	29.36	30.07	......	35.2	......	57	29	41	18	15	29	30	32	28	79	1.46	− 0.8	11	8,131	sw.	53	sw.	29	2	9	19	7.8	0.8	0.4
Sault Ste. Marie	614	11	52	29.31	30.03	+ .02	29.8	− 0.9	54	10	56	− 4	26	24	25	28	25	83	4.62	+ 1.7	21	7,576	se.	38	nw.	22	3	4	23	8.3	18.9	4.5
Chicago	823	140	310	29.19	30.09	+ .02	39.2	0.0	60	10	46	15	30	33	36	35	30	68	2.38	− 0.1	6	10,908	w.	50	sw.	29	9	8	13	6.1	0.6	0.0
Green Bay	617	109	144	29.36	30.04	.00	31.6	− 0.9	58	10	38	0	30	25	26	29	25	76	2.26	+ 0.3	13	10,023	sw.	56	sw.	10	8	5	17	6.9	5.8	1.5
Milwaukee	681	119	133	29.30	30.06	+ .01	35.6	− 0.5	58	10	42	8	30	29	29	32	28	74	2.23	+ 0.2	10	9,551	sw.	48	sw.	10	10	7	13	6.0	4.0	T.
Duluth	1,133	11	47	28.79	30.06	+ .02	21.6	− 7.7	50	17	28	−18	30	15	28	20	18	88	3.86	+ 2.3	15	11,888	nw.	53	nw.	29	10	7	13	5.1	28.7	11.0
North Dakota.							15.8	− 8.7										85	1.08	+ 0.3										5.5		
Moorhead	940	8	57	29.08	30.15	+ .08	17.4	− 7.0	44	17	25	−14	30	10	31	16	14	87	1.92	+ 0.9	9	6,938	n.	36	nw.	10	14	4	12	5.2	18.4	3.2
Bismarck	1,674	8	57	28.31	30.18	+ .11	18.2	− 7.8	49	22	26	−14	30	10	33	17	14	84	0.92	+ 0.2	4	7,678	nw.	40	nw.	10	8	8	14	6.2	11.7	1.0
Devils Lake	1,482	11	44	28.46	30.12	+ .06	12.8	− 9.8	39	21	21	−20	30	5	31	12	10	89	1.01	+ 0.3	8	9,026	w.	46	n.	10	8	7	15	6.5	14.9	4.0
Ellendale	1,457	10	56	28.51	30.13	......	18.5	......	50	22	26	−12	13	11	34	18	15	87	0.95	......	6	11,394	nw.	66	nw.	10	2	13	15	7.4	12.2	0.7
Grand Forks	835	12	89	......	......	......	12.1	......	40	17	21	−24	26	3	36	....	....	....	2.25	......	9	......	w.	63	n.	10	15	7	8	4.4	23.9	15.0
Williston	1,878	41	48	28.07	30.14	+ .08	15.0	−10.2	48	16	24	−20	30	6	34	14	10	81	0.46	− 0.1	5	6,260	w.	36	e.	4	8	14	8	5.4	3.8	0.1
Upper Mississippi Valley.							36.9	− 0.9										75	3.18	+ 1.2										6.1		
Minneapolis	918	10	208	29.05	30.06	......	26.6	......	56	10	34	− 8	30	20	36	....	....	....	2.73	+ 1.6	11	9,076	w.		w.	10	7	6	17	6.7	11.0	6.6
St. Paul	837	236	261	29.14	30.08	+ .02	26.6	− 4.3	55	10	34	− 8	30	19	36	....	....	....	2.59	+ 1.3	11	9,487	nw.	50	s.	10	6	7	17	7.0	12.6	6.0
La Crosse	714	11	48	29.28	30.07	.00	31.1	− 2.7	59	10	39	4	30	23	30	....	....	....	3.29	+ 1.8	10	4,506	s.	31	sw.	10	6	4	20	7.4	13.1	6.0
Madison	974	70	78	29.01	30.10	+ .04	32.6	− 1.6	57	10	40	5	30	26	26	29	24	74	2.25	+ 0.4	9	8,474	w.	45	sw.	10	7	5	18	7.1	2.9	1.7
Wausau	1,247	4	....	28.66	30.04	......	27.8	......	58	10	35	− 5	30	21	33	....	....	....	2.81	......	13	......	nw.	......	......	......	12	4	14	5.6	11.4	6.8
Charles City	1,015	10	49	28.98	30.10	+ .02	30.4	− 2.6	58	10	39	2	30	22	34	27	24	82	3.78	+ 2.4	10	6,000	nw.	36	sw.	10	5	12	13	6.4	8.9	6.7
Davenport	606	71	79	29.43	30.11	+ .03	36.6	− 0.9	59	9	44	12	30	29	25	32	28	76	2.70	+ 0.9	8	6,497	w.	40	sw.	10	10	7	13	5.9	0.5	T.
Des Moines	861	84	97	29.16	30.09	+ .01	35.7	− 1.1	59	10	45	5	30	27	31	31	26	72	3.84	+ 2.4	8	5,652	nw.	48	sw.	10	6	10	14	6.6	6.7	5.2
Dubuque	698	81	96	29.34	30.12	+ .05	34.6	− 1.4	58	10	42	8	30	27	26	30	26	74	3.59	+ 1.8	7	5,554	nw.	33	sw.	10	7	11	12	6.4	1.4	1.5
Keokuk	614	64	78	29.43	30.13	+ .04	39.3	− 0.1	60	10	48	13	30	31	30	34	29	71	2.53	+ 0.7	9	6,460	nw.	63	sw.	10	12	7	11	5.4	1.6	T.
Cairo	356	87	93	29.72	30.11	− .01	47.8	+ 0.9	67	23	56	23	13	39	35	43	39	78	6.47	+ 2.4	9	6,665	n.	56	sw.	29	13	4	13	5.3	0.0	0.0
Peoria	609	11	45	29.43	30.11	+ .02	37.9	+ 0.4	63	9	47	14	13	29	28	34	30	81	2.91	+ 0.3	9	6,114	w.	37	sw.	29	7	13	10	5.7	0.9	0.0
Springfield, Ill	644	10	91	29.40	30.10	.00	40.6	− 0.1	64	9	49	17	13	33	27	36	32	77	3.10	+ 0.4	9	6,773	w.	36	sw.	29	9	10	11	5.4	0.1	0.0
Hannibal	534	74	109	29.52	30.10	+ .01	41.1	+ 0.6	62	23	50	15	30	32	28	....	....	....	2.63	+ 0.7	8	7,149	sw.	48	sw.	10	11	8	11	5.5	0.3	0.0
St. Louis	567	265	303	29.48	30.10	.00	44.8	+ 1.4	68	3	53	20	13	37	31	39	33	69	2.08	− 0.8	7	9,801	nw.	64	sw	29	14	6	10	4.8	T.	0.0
Missouri Valley.							34.9	− 2.5										76	2.62	+ 1.4										5.6		
Columbia, Mo.	781	11	84	29.25	30.10	+ .01	42.2	− 0.2	64	23	51	16	13	33	30	....	....	....	2.84	+ 0.5	9	6,502	se.	39	sw.	29	16	4	10	4.9	0.1	0.0
Kansas City	963	161	181	29.05	30.11	+ .03	41.3	− 0.2	66	23	50	13	30	33	32	35	29	67	2.44	+ 0.6	6	9,371	n.	46	sw.	10	17	3	10	4.6	2.6	2.0
St. Joseph	967	11	49	29.04	30.10	......	39.6	......	65	24	49	9	30	30	36	34	29	71	2.44	......	8	6,610	nw.	39	nw.	11	14	7	9	4.9	2.4	1.8
Springfield, Mo.	1,324	98	104	28.68	30.10	.00	44.4	0.0	68	23	54	17	13	35	27	38	34	75	4.49	+ 1.8	9	8,181	se.	36	w.	29	14	5	11	4.9	T.	0.0
Iola	984	11	50	29.03	30.10	+ .01	43.0	0.0	73	23	54	15	13	32	35	....	....	....	2.12	+ 0.7	4	5,302	n.	27	ne.	25	14	6	10	5.0	T.	T.
Topeka	987	92	107	......	......	......	40.3	− 1.4	70	24	50	12	30	30	39	....	....	....	2.19	+ 0.9	6	7,782	n.	42	n.	11	10	11	9	5.1	3.4	2.5
Drexel	1,299	10	53	28.64	30.07	......	33.8	......	60	17	43	− 1	30	24	38	29	25	80	2.79	......	9	8,369	nw.	44	nw.	10	7	9	14	6.5	8.9	7.0
Lincoln	1,189	11	84	28.81	30.11	+ .03	36.1	− 1.9	64	17	46	3	30	27	43	31	27	76	3.20	+ 2.4	9	7,758	n.	44	nw.	10	9	9	12	5.8	8.9	6.6
Omaha	1,105	115	122	28.90	30.12	+ .04	36.0	− 1.7	62	24	45	4	30	27	40	30	26	72	2.84	+ 1.8	9	6,748	nw.	32	nw.	11	8	10	12	6.1	11.8	8.0
Valentine	2,598	47	54	27.33	30.15	+ .07	25.2	− 8.5	59	2	35	− 8	12	16	39	23	20	83	2.61	+ 1.9	10	7,209	w.	42	nw.	10	10	10	10	5.5	33.7	9.0
Sioux City	1,135	94	164	28.87	30.12	+ .04	31.6	− 2.7	58	2	39	1	13	24	36	28	24	79	3.15	+ 2.2	10	8,006	nw.	52	w.	10	8	6	16	6.4	10.2	7.6
Huron	1,306	59	74	28.70	30.15	+ .07	23.7	− 3.7	51	24	31	−10	13	16	36	21	18	82	1.77	+ 1.2	10	8,647	nw.	43	n.	10	8	13	9	5.8	11.6	0.8
Pierre	1,572	70	75	28.43	30.16	+ .08	25.3	− 6.3	58	24	34	− 6	13	17	43	22	18	77	1.27	+ 0.8	6	7,060	nw.	42	nw.	10	8	10	12	6.3	13.8	0.4
Yankton	1,233	49	57	28.74	30.11	+ .03	29.8	− 3.7	61	2	38	8	13	22	35	....	....	....	2.56	+ 1.8	12	6,269	nw.	38	nw.	10	5	12	13	6.9	10.7	8.0

TABLE I.—*Climatological data for Weather Bureau stations, November, 1919*—Continued.

Districts and stations.	Elevation of instruments. Barometer above sea level.	Elevation of instruments. Thermometer above ground.	Elevation of instruments. Anemometer above ground.	Pressure. Station, reduced to mean of 24 hours.	Pressure. Sea level, reduced to mean of 24 hours.	Pressure. Departure from normal.	Temperature of the air. Mean max.+mean min.÷2.	Temperature of the air. Departure from normal.	Temperature of the air. Maximum.	Temperature of the air. Date.	Temperature of the air. Mean maximum.	Temperature of the air. Minimum.	Temperature of the air. Date.	Temperature of the air. Mean minimum.	Temperature of the air. Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation. Total.	Precipitation. Departure from normal.	Precipitation. Days with 0.01 inch or more.	Wind. Total movement.	Wind. Prevailing direction.	Wind. Maximum velocity. Miles per hour.	Wind. Maximum velocity. Direction.	Wind. Maximum velocity. Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
Northern Slope.							**25.4**	**− 6.7**										**74**	**1.44**	**+ 0.6**										**5.2**		
Billings	3,140	5																														
Havre	2,505	11	44	27.40	30.15	+ .12	21.2	− 9.4	58	17	31	−18	27	11	42	18	16	85	0.90	+ 0.1	7	5,779	sw.	38	sw.	16	11	5	14	5.9	9.0	4.3
Helena	4,110	87	112	25.83	30.18	+ .08	24.8	− 7.9	56	23	34	−12	27	16	33	21	17	74	1.07	+ 0.4	8	4,500	sw.	30	sw.	2	6	5	19	6.9	17.2	6.2
Kalispell	2,962	11	34	......	30.14	+ .07	26.7	− 5.3	57	22	34	− 1	11	19	25	....	....	....	1.35	− 0.6	12	3,140	nw.	28	ne.	10	3	11	16	....	12.5	3.5
Miles City	2,371	26	48																													
Rapid City	3,259	50	58	26.63	30.18	+ .10	28.4	− 5.2	62	16	38	− 3	12	18	40	24	18	69	0.71	+ 0.2	7	6,113	w.	35	nw.	3	7	12	11	5.9	8.1	4.2
Cheyenne	6,088	84	101	23.95	30.07	00	30.6	− 4.3	62	23	41	−12	28	20	41	25	18	66	1.63	+ 1.2	8	10,477	w.	66	w.	2	12	8	10	5.3	15.6	4.0
Lander	5,372	60	68	24.64	30.22	+ .12	20.1	− 8.6	58	4	32	−22	12	8	39	16	9	67	2.20	+ 1.6	6	2,492	sw.	34	w.	1	9	11	10	5.7	25.9	2.7
Sheridan	3,790	10	47	26.13	30.18	......	24.4	......	59	23	36	−14	27	13	40	20	16	78	1.05	......	10	3,266	nw.	24	nw.	24	11	5	14	6.1	15.0	5.0
Yellowstone Park	6,200	11	48	23.86	30.18	+ .07	23.2	− 6.1	48	18	33	−19	27	13	36	20	15	72	0.80	− 0.6	11	5,890	s.	35	s.	4	8	8	14	6.0	6.4	6.0
North Platte	2,821	11	51	27.13	30.18	+ .10	28.2	− 6.9	63	23	38	− 8	12	18	35	23	20	81	2.83	+ 2.4	10	5,237	w.	35	nw.	10	14	2	14	5.4	20.5	8.5
Middle Slope.							**39.2**	**− 2.6**										**71**	**1.60**	**+ 0.6**										**4.3**		
Denver	5,292	106	113	24.70	30.08	+ .02	34.6	− 4.6	68	23	46	− 6	28	23	45	27	20	62	1.29	+ 0.8	6	5,229	s.	39	ne.	5	12	7	11	5.1	13.1	0.5
Pueblo	4,685	80	86	25.28	30.07	− .01	36.8	− 2.5	72	5	52	0	27	21	47	28	20	61	0.64	+ 0.3	6	4,373	nw.	42	w.	11	16	5	9	3.8	5.5	0.4
Concordia	1,392	50	58	28.61	30.13	+ .06	38.2	− 1.7	66	17	49	6	30	28	45	32	28	77	1.71	+ 0.8	8	6,388	nw.	33	nw.	11	14	5	11	5.3	3.8	3.0
Dodge City	2,509	11	51	27.46	30.13	+ .06	38.7	− 1.8	77	5	52	5	27	25	48	31	26	75	1.11	+ 0.6	7	7,465	nw.	40	nw.	11	21	0	9	3.5	2.5	0.5
Wichita	1,358	139	158	28.64	30.10	+ .02	41.5	− 2.3	69	23	52	14	12	31	38	36	32	75	1.99	+ 0.8	4	9,784	s.	46	nw.	11	16	6	8	4.1	1.5	2.0
Altus	1,410	5	....	......	......	......	47.2	......	77	23	58	20	27	36	39	....	....	....	1.99	......	6	......	n.	....	......	....	19	0	11	....	0.6	0.0
Muskogee	652	4	....	......	......	......	48.2	......	78	23	59	20	13	37	38	....	....	....	4.05	......	9	......	n.	....	......	....	17	3	10	....	0.0	0.0
Oklahoma	1,214	10	47	28.80	30.11	+ .03	45.4	− 2.5	73	24	56	19	13	35	31	40	36	78	2.84	+ 0.6	8	9,377	s.	43	n.	12	15	7	8	4.1	0.2	0.9
Southern Slope.							**49.4**	**− 1.5**										**70**	**1.55**	**+ 0.4**										**4.8**		
Abilene	1,738	10	52	28.25	30.09	+ .02	50.4	− 2.2	79	3	62	21	13	39	41	44	40	77	1.13	− 0.1	9	6,180	s.	28	w.	9	12	6	12	5.2	T.	T.
Amarillo	3,676	10	49	26.29	30.08	+ .03	42.6	− 1.2	77	2	56	6	27	29	50	35	30	71	1.26	+ 0.1	6	7,395	sw.	40	n.	11	15	10	5	4.0	2.7	T.
Del Rio	944	64	71	29.04	30.04	− .01	58.4	− 0.9	83	4	68	32	29	49	36	....	....	....	3.27	+ 2.1	9	5,582	se.	38	nw.	28	10	7	13	5.7	0.0	0.0
Roswell	3,566	75	85	26.38	30.03	00	46.4	− 1.7	79	3	60	10	28	33	46	38	30	62	0.55	− 0.6	6	4,728	s.	33	w.	9	12	10	8	4.3	2.4	0.0
Southern Plateau.							**48.4**	**− 0.5**										**53**	**0.87**	**+ 0.3**										**3.0**		
El Paso	3,762	110	133	26.20	29.99	− .01	52.4	+ 1.5	76	8	63	28	30	42	34	43	34	57	0.93	+ 0.3	9	8,351	w.	49	sw.	8	16	10	4	3.8	0.5	0.0
Santa Fe	7,013	57	66	23.20	30.00	− .03	38.6	+ 0.4	61	17	49	9	28	28	28	30	22	59	0.75	00	8	6,067	n.	42	s.	8	15	7	8	4.0	3.2	0.0
Flagstaff	6,908	8	57	23.30	29.96	− .06	36.2	+ 1.6	64	4	49	0	29	23	44	28	....	....	5.50	......	7	......	......	44	s.	26	16	12	2	3.0	30.3	13.0
Phoenix	1,108	76	81	28.78	29.95	− .03	57.0	− 1.7	84	16	71	29	29	43	44	47	40	64	2.38	+ 1.4	6	3,752	e.	36	s.	27	19	4	7	3.4	T.	0.0
Yuma	141	9	54	29.79	29.94	− .04	60.0	− 1.9	84	16	73	31	28	47	38	48	37	52	0.28	00	3	4,027	n.	30	w.	7	21	5	4	2.2	0.0	0.0
Independence	3,957	11	42	26.00	30.08	+ .03	46.1	− 3.1	71	24	61	18	27	32	38	32	16	34	0.03	− 0.3	1	5,153	n.	38	n.	26	24	6	0	1.9	0.2	0.0
Needles	488	4	....	29.45	29.97	......	52.1	......	76	22	63	28	30	41	16	....	....	....	0.82	......	4	......	......	....	......	....	18	5	7	2.1	....	....
Middle Plateau.							**37.1**	**− 2.5**										**60**	**0.82**	**− 0.1**										**3.9**		
Reno	4,532	74	81	25.53	30.14	+ .03	39.2	− 1.8	68	3	55	6	28	24	44	31	23	58	0.18	− 0.9	4	4,045	w.	37	w.	30	20	7	3	2.9	1.9	0.0
Tonopah	6,090	12	20	24.08	30.08	......	39.0	......	61	23	48	3	27	30	32	29	17	46	0.20	− 0.7	2	6,097	w.	36	nw.	8	21	5	4	2.7	3.5	1.0
Winnemucca	4,344	18	56	25.68	30.16	+ .02	36.0	− 1.5	67	4	51	− 1	28	21	44	29	23	67	0.72	0.0	5	5,256	ne.	34	sw.	4	16	6	8	4.0	1.2	0.0
Modena	5,479	10	43	24.61	30.05	− .03	34.8	− 4.2	63	3	50	− 4	28	19	44	27	19	61	1.12	+ 0.5	4	7,305	w.	39	sw.	26	17	7	6	3.3	15.8	9.2
Salt Lake City	4,360	163	203	25.65	30.09	− .03	38.4	− 2.0	67	4	46	10	27	31	22	33	27	67	0.81	− 0.6	8	4,606	se.	42	ne.	27	12	4	14	5.6	6.7	0.0
Grand Junction	4,602	82	96	25.40	30.04	− .04	37.0	− 2.9	63	5	49	12	27	25	36	30	23	64	1.89	+ 1.3	6	3,162	se.	29	s.	9	12	7	9	4.9	23.6	10.7
Northern Plateau.							**36.5**	**− 2.2**										**75**	**2.00**	**+ 0.6**										**6.5**		
Baker	3,471	48	53	26.51	30.17	+ .01	33.5	− 1.4	56	17	41	3	27	26	27	29	26	79	1.61	+ 0.4	10	4,025	se.	31	n.	26	8	6	16	6.6	5.0	3.0
Boise	2,739	78	86	27.25	30.17	.00	37.0	− 2.6	58	4	45	8	27	29	24	34	29	73	2.34	+ 1.5	9	3,006	nw.	31	w.	8	13	5	12	5.5	3.9	T.
Lewiston	757	40	48	......	30.15	+ .03	39.4	− 1.5	62	1	47	12	27	32	24	....	....	....	2.55	+ 1.2	13	2,678	e.	29	n.	10	3	7	20	....	10.6	8.0
Pocatello	4,477	60	68	25.51	30.12	− .02	34.3	− 2.0	64	4	43	− 3	28	25	30	30	25	71	0.55	0.0	10	6,653	se.	38	sw.	11	10	7	13	6.1	3.7	0.5
Spokane	1,929	101	110	28.04	30.15	+ .05	34.2	− 3.1	61	16	40	7	27	28	24	32	28	77	1.82	− 0.5	12	3,961	ne.	32	sw.	1	6	4	20	7.5	8.9	5.0
Walla Walla	991	57	65	29.05	30.14	+ .01	40.5	− 2.4	70	16	48	12	27	34	29	36	32	73	3.16	+ 1.0	11	3,601	s.	38	sw.	1	4	10	16	7.0	3.2	2.0
North Pacific Coast Region.							**44.9**	**− 0.7**										**85**	**6.39**	**− 0.6**										**8.0**		
North Head	211	11	56	29.86	30.10	+ .05	45.8	− 1.9	59	22	49	32	27	42	13	44	42	86	6.53	+ 0.2	21	11,811	se.	70	se.	14	2	7	21	8.1	0.0	0.0
North Yakima	1,071	4	....	......	......	......	37.8	......	62	17	47	7	27	28	34	....	....	....	0.50	......	6	......	n.	....	......	....	6	10	14	....	2.3	T.
Port Angeles	29	8	48	30.07	30.10	......	41.7	......	59	15	47	25	27	37	19	....	....	....	3.55	− 0.9	19	4,037	s.	35	nw.	23	2	2	26	8.8	0.1	0.0
Seattle	125	215	250	29.97	30.11	+ .07	44.9	+ 0.4	64	17	49	28	27	41	14	43	40	83	4.13	− 1.7	22	6,957	se.	45	s.	1	2	2	26	8.8	T.	0.0
Tacoma	213	113	120	29.87	30.10	+ .06	44.6	+ 0.5	64	22	49	25	27	40	20	44	42	90	4.52	− 4.0	21	4,335	sw.	30	sw.	1	1	3	26	8.9	T.	0.0
Tatoosh Island	86	7	57	29.94	30.04	+ .07	44.1	− 1.8	55	17	47	35	26	42	10	43	41	87	14.66	+ 2.6	23	14,254	e.	64	s.	15	4	2	24	8.3	0.0	0.0
Medford	1,425	4	....	......	......	......	39.6	......	66	3	48	13	27	32	30	....	....	....	1.87	......	13	......	nw.	....	......	....	3	9	18	....	0.0	0.0
Portland, Oreg.	153	68	106	29.96	30.13	+ .03	45.0	− 0.6	65	16	50	26	27	40	18	43	40	81	7.44	+ 1.0	15	4,116	se.	30	e.	26	5	9	16	7.2	0.0	0.0
Roseburg	510	9	57	29.62	30.18	+ .06	44.8	− 0.8	62	17	52	17	27	37	24	42	40	84	3.90		12	1,839	s.	24	sw.	4	6	15	9	5.7	0.0	0.0
Middle Pacific Coast Region.							**52.0**	**− 1.0**										**59**	**0.88**	− 0.5 − 2.3										**3.3**		
Eureka	62	73	89	30.10	30.16	+ .05	48.2	− 2.8	65	3	54	32	27	42	20	46	44	85	2.99	− 2.7	12	4,246	n.	42	n.	26	4	10	16	6.7	0.0	0.0
Mount Tamalpais	2,375	11	31	27.59	30.07	− .02	51.8	+ 1.2	72	17	58	27	27	46	19	42	29	49	1.09	− 2.6	6	15,538	nw.	88	n.	27	22	5	3	2.4	0.0	0.0
Point Reyes Light	490	7	18	29.51	30.03	......	51.6	− 1.4	75	17	57	38	27	46	25				0.40	......	4	15,966	nw.	73	nw.	7	14	6	10	4.7	0.0	0.0
Red Bluff	332	50	56	29.73	30.09	− .03	52.3	− 1.1	82	22	66	30	27	39	45	43	31	50	0.32	− 2.9	5	4,429	nw.	36	nw.	27	21	5	4	3.0	0.0	0.0
Sacramento	69	106	117	29.99	30.06	− .03	52.4	− 1.0	74	3	65	30	28	40	32	44	32	50	0.36	− 1.8	4	5,419	nw.	48	nw.	26	24	4	2	2.1	0.0	0.0
San Francisco	155	208	243	29.90	30.07	− .02	56.0	+ 0.5	73	17	64	38	27	48	23	48	40	62	0.44	− 2.0	2	6,928	n.	62	ne.	27	24	3	3	2.1	0.0	0.0
San Jose	141	12	110	29.92	30.07	......	52.0	− 2.4	76	16	66	32	10	38	43	....	....	....	0.09	− 1.8	5	4,226	nw.	35	n.	27	22	5	3	2.2	0.0	0.0
South Pacific Coast Region.							**57.4**	**− 0.2**										**56**	**0.27**	**− 1.0**										**2.0**		
Fresno	327	89	98	29.70	30.06	.00	53.0	− 1.6	74	23	66	30	28	40	32	43	30	45	0.04	− 1.0	2	3,599	nw.	29	nw.	26	25	3	2	1.4	0.0	0.0
Los Angeles	338	159	191	29.63	30.00	− .02	61.5	+ 1.2	88	16	71	37	28	52	30	50	42	58	0.46	− 1.0	2	4,029	ne.	23	nw.	7	21	6	3	2.4	T.	0.0
San Diego	87	62	70	29.88	29.97	− .05	58.6	− 0.4	82	21	67	36	28	50	30	51	46	68	0.43	− 0.4	3	4,292	nw.	34	w.	7	19	5	6	3.0	0.0	0.0
San Luis Obispo	201	32	40	29.82	30.04	− .02	56.4	+ 0.1	89	22	72	24	28	41	48	45	34	54	0.14	− 1.6	2	2,691	n.	22	w.	7	25	3	2	1.4	0.0	0.0
West Indies.																																
San Juan, P. R.	82	8	54	29.84	29.92	......	77.2	......	85	15	82	67	11	72	15	....	....	....	5.83	− 1.1	15	6,230	s.	35	e.	27	12	10	8	4.8	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.72	29.85	.00	79.1	+ 0.1	90	12	86	70	14	72	18	74	73	84	4.97	− 5.1	17	4,327	n.	32	ne.	21	1	19	10	6.8	0.0	0.0
Colon	36	15	97	29.81	29.84	.00	80.0	− 1.2	89	8	85	72	8	76	17	76	74	81	6.63	−14.4	22	7,197	n.	33	n.	28	2	15	13	6.9	0.0	0.0

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during November, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	9			0.33														0.29			
Albany, N. Y.	4			0.32														0.27			
Alpena, Mich.	28–29			1.13														(*)			
Amarillo, Tex.	8			0.60														0.53			
Anniston, Ala.	1	1:14 p.m.	3:00 p.m.	1.40	1:14 p.m.	2:15 p.m.	0.00	0.12	0.20	0.31	0.44	0.52	0.58	0.75	0.90	1.00	1.07	1.22	1.31		
Asheville, N. C.	29			0.25														0.11			
Atlanta, Ga.	29			0.76														0.47			
Atlantic City, N. J.	1			1.16														0.72			
Augusta, Ga.	1			0.19														0.15			
Baker, Oreg.	2–3			0.52														(*)			
Baltimore, Md.	1			0.79														0.69			
Bentonville, Ark.	25			2.46														0.49			
Binghamton, N. Y.	4			0.53														0.24			
Birmingham, Ala.	10			1.67														0.54			
Bismarck, N. Dak.	8			0.71														(*)			
Block Island, R. I.	30			0.72														0.42			
Boise, Idaho.	29–30			0.76														(*)			
Boston, Mass.	30			0.44														0.20			
Buffalo, N. Y.	4			0.68														0.15			
Burlington, Vt.	4–5			1.06														(*)			
Cairo, Ill.	1			1.39														0.61			
Canton, N. Y.	3–4			0.33														(*)			
Charles City, Iowa.	9–10			2.58														(*)			
Charleston, S. C.	30			0.11														0.09			
Charlotte, N. C.	13			0.47														0.47			
Chattanooga, Tenn.	29			0.82														0.35			
Cheyenne, Wyo.	25–26			0.51														(*)			
Chicago, Ill.	29			1.19														0.20			
Cincinnati, Ohio.	29			0.61														0.21			
Cleveland, Ohio.	4			0.14														0.08			
Columbia, Mo.	6			0.75														0.48			
Columbia, S. C.	1			0.04														0.04			
Columbus, Ohio.	25			0.70														0.27			
Concord, N. H.	26–27			1.28														(*)			
Concordia, Kans.	9			0.91														0.40			
Corpus Christi, Tex.	10			0.20														0.13			
Dallas, Tex.	28			2.06														0.72			
Davenport, Iowa.	9–10			1.14														(*)			
Dayton, Ohio.	29			0.55														0.20			
Del Rio, Tex.	6	7:45 p.m.	10:45 p.m.	2.45	8:01 p.m.	8:46 p.m.	0.06	0.12	0.25	0.48	0.69	1.01	1.32	1.58	1.83	1.99					
Denver, Colo.	9			0.61														(*)			
Des Moines, Iowa.	8–10	9:25 p.m.	D. N. a.m.	2.65	12:01 p.m.[1]	12:27 p.m.[1]	0.81	0.25	0.28	0.37	0.49	0.53	0.57								
Detriot, Mich.	29			1.43														(*)			
Devils Lake, N. Dak.	9–10			0.30														(*)			
Dodge City, Kans.	9			0.60														0.22			
Drexel, Nebr.	9			1.16														0.22			
Dubuque, Iowa.	9–10			2.02														(*)			
Duluth, Minn.	9–10			1.36														(*)			
Eastport, Me.	18			0.74														0.23			
Elkins, W. Va.	1			1.31														0.28			
Ellendale, N. Dak.	9–10			0.64														(*)			
El Paso, Tex.	21			0.42														0.31			
Erie, Pa.	4			0.36														0.15			
Escanaba, Mich.	10			0.90														0.15			
Eureka, Calif.	4			0.61														0.32			
Evansville, Ind.	10			0.53														0.23			
Flagstaff, Ariz.	26–27			3.59														(*)			
Fort Smith, Ark.	25			0.41														0.33			
Fort Wayne, Ind.	29			1.43														(*)			
Fort Worth, Tex.	27–28			2.27														(*)			
Fresno, Calif.	26			0.02														0.01			
Galveston, Tex.	9–10			1.26														0.41			
Grand Haven, Mich.	29			1.05														0.19			
Grand Junction, Colo.	26–27			1.29														(*)			
Grand Rapids, Mich.	29			1.13														0.18			
Green Bay, Wis.	28–29			1.00														(*)			
Greenville, S. C.	1			0.51														0.47			
Hannibal, Mo.	28–29			1.08														(*)			
Harrisburg, Pa.	4			0.51														0.33			
Hartford, Conn.	5			0.96														0.30			
Hatteras, N. C.	2			0.13														0.12			
Havre, Mont.	10			0.32														(*)			
Helena, Mont.	10–11			0.56														(*)			
Houghton, Mich.	29–30			2.40														(*)			
Houston, Tex.	29–30			2.40														(*)			
Huron, S. Dak.	9–10			0.74														(*)			
Independence, Calif.	26			0.03														(*)			
Indianapolis, Ind.	1			0.91														(*)			
Iola, Kans.	9			1.15														0.73			
Jacksonville, Fla.	30			0.44														0.21			
Kalispell, Mont.																					
Kansas City, Mo.	28–29			1.21														(*)			
Keokuk, Iowa.	9			0.81														0.20			
Key West, Fla.	6	D. N. a.m.	8:30 a.m.	3.00	1:33 a.m.	1:58 a.m.	0.07	0.08	0.15	0.49	0.63	0.73									
					2:42 a.m.	3:34 a.m.	1.00	0.23	0.41	0.65	0.80	0.86	0.90	0.92	0.94	0.99	1.11	1.16			
Knoxville, Tenn.	29			0.35														0.19			
La Crosse, Wis.	9			1.77														0.31			
Lander, Wyo.	7–8			1.60														(*)			
Lansing, Mich.	28–29			1.34														(*)			
Lewiston, Idaho.	4			0.76														0.15			
Lexington, Ky.	1			3.34														0.69			
Lincoln, Nebr.	9			1.35														0.33			
Little Rock, Ark.	9–10	4:45 p.m.	D. N. a.m.	1.89	10:39 p.m.	11:07 p.m.	0.97	0.09	0.19	0.44	0.57	0.64	0.69								
	25–26	3:20 p.m.	D. N. a.m.	2.22	3:24 p.m.	3:41 p.m.	0.01	0.32	0.47	0.59	0.65										
Los Angeles, Calif.	27			0.24														0.14			
Louisville, Ky.	25			1.51														0.35			
Ludington, Mich.	28–29			1.33														(*)			
Lynchburg, Va.	13			0.29														0.24			

* Self-register not in use.

[1] Of 9th.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during November, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Macon, Ga.	26			0.21														0.16			
Madison, Wis.	9			0.55														0.22			
Marquette, Mich.	3-4			0.89														(*)			
Memphis, Tenn.	9	8:20 a.m.	1:45 p.m.	0.95	12:03 p.m.	12:32 p.m.	0.32	0.19	0.27	0.35	0.42	0.49	0.56								
Meridian, Miss.	10	D.N.a.m.	5:00 p.m.	3.13	7:32 a.m.	8:01 a.m.	0.74	0.13	0.22	0.28	0.44	0.58	0.64								
Miami, Fla.	4	4:20 p.m.	4:45 p.m.	0.56	4:24 p.m.	4:38 p.m.	0.01	0.14	0.42	0.54											
	6	6:24 p.m.	6:58 p.m.	0.57	6:24 p.m.	6:47 p.m.	0.00	0.15	0.25	0.39	0.49	0.55									
Milwaukee, Wis.	10			0.57														0.12			
Minneapolis, Minn.	9			1.17														(*)			
Mobile, Ala.	10	9:15 a.m.	8:30 p.m.	3.00	2:43 p.m.	3:05 p.m.	0.42	0.13	0.25	0.44	0.73	0.78									
					4:46 p.m.	5:16 p.m.	1.61	0.17	0.33	0.47	0.63	0.81	0.88								
Modena, Utah	26-27			0.90														(*)			
Montgomery, Ala.	10			1.52														0.53			
Moorhead, Minn.	9-10			1.24														(*)			
Mount Tamalpais, Calif.	30			0.77														0.23			
Nantucket, Mass.	4			1.39														0.30			
Nashville, Tenn.	25			3.01														0.70			
New Haven, Conn.	5			0.73														0.37			
New Orleans, La.	9-10	D. N. p.m.	7:17 a.m.	2.11	12:23 a.m.	1:23 a.m.	0.51	0.06	0.12	0.23	0.32	0.42	0.52	0.59	0.79	0.99	1.10	1.36			
New York, N. Y.	4-5			0.61														0.44			
Norfolk, Va.	13			0.12														0.08			
Northfield, Vt.	5			0.86														(*)			
North Head, Wash.	4			0.70														0.26			
North Platte, Nebr.	9-10			1.00														(*)			
Oklahoma, Okla.	9	D. N. a.m.	4:00 p.m.	0.98	12:09 p.m.	12:39 p.m.	0.03	0.10	0.14	0.28	0.42	0.47	0.58								
Omaha, Nebr.	9			1.27														0.27			
Oswego, N. Y.																					
Palestine, Tex.	9	4:47 p.m.	D. N. p.m.	4.01	5:01 p.m.	6:54 p.m.	0.00	0.08	0.38	0.77	0.94	1.02	1.17	1.53	1.49	2.23	2.27	2.47	2.50	2.88	3.23
	25	6:03 p.m.	D. N. p.m.	1.24	6:17 p.m.	6:56 p.m.	0.01	0.18	0.32	0.35	0.49	0.62	0.68	0.83	0.91						
Parkersburg, W. Va.	25			1.64														0.51			
Pensacola, Fla.	10	6:46 p.m.	10:15 p.m.	1.30	7:09 p.m.	8:07 p.m.	0.11	0.26	0.34	0.38	0.44	0.49	0.51	0.56	0.61	0.70	0.75	0.84			
Peoria, Ill.	28			1.01														0.36			
Philadelphia, Pa.	4			0.45														0.37			
Phoenix, Ariz.	27			1.29														0.50			
Pierre, S. Dak.	9-10			0.78														(*)			
Pittsburgh, Pa.	26			1.54														0.29			
Pocatello, Idaho	25-26			0.16														(*)			
Point Reyes Light, Calif.	30			0.21														0.08			
Port Angeles, Wash.	16			0.78														0.23			
Port Huron, Mich.	29			1.07														(*)			
Portland, Me.	30			0.37														0.20			
Portland, Oreg.	6			0.86														0.33			
Providence, R. I.	30			0.75														0.31			
Pueblo, Colo.	8-9			0.30														(*)			
Raleigh, N. C.	1	7:21 p.m.	8:15 p.m.	1.06	7:23 p.m.	7:59 p.m.	0.01	0.51	0.77	0.77	0.77	0.77	0.88	0.98	1.04						
Rapid City, S. Dak.	25-26			0.24														(*)			
Reading, Pa.	4			0.86														0.43			
Red Bluff, Calif.	30			0.24														0.05			
Reno, Nev.	7			0.14														(*)			
Richmond, Va.	30			0.13														0.11			
Rochester, N. Y.	4			0.44														0.35			
Roseburg, Oreg.	4			0.41														0.15			
Roswell, N. Mex.	7			0.10														0.10			
Sacramento, Calif.	7			0.17														0.16			
Saginaw, Mich.	29			0.81														0.11			
St. Joseph, Mo.	9			1.13														0.23			
St. Louis, Mo.	6			0.70														0.30			
St. Paul, Minn.	9-10			1.22														(*)			
Salt Lake City, Utah	7-8			0.56														(*)			
San Antonio, Tex.	1	3:37 a.m.	4:56 a.m.	0.94	3:37 a.m.	4:40 a.m.	0.00	0.08	0.15	0.28	0.37	0.46	0.52	0.59	0.65	0.71	0.75	0.83	0.94		
San Diego, Calif.	26			0.22														0.11			
Sand Key, Fla.	(‡)			(‡)														(‡)			
Sandusky, Ohio	29			0.39														0.14			
Sandy Hook, N. J.	1			0.73														0.34			
San Francisco, Calif.	30			0.41														0.09			
San Jose, Calif.	6			0.02														0.02			
San Luis Obispo, Calif.	26			0.10														0.03			
Santa Fe, N. Mex.	19-20			0.31														(*)			
Sault Ste. Marie, Mich.	28-29			1.18														(*)			
Savannah, Ga.	1			0.26														0.26			
Scranton, Pa.	25-26			0.91														(*)			
Seattle, Wash.	15			1.00														0.16			
Sheridan, Wyo.	7-8			0.46														(*)			
Shreveport, La.	9	9:30 p.m.	11:55 p.m.	0.77	9:51 p.m.	10:10 p.m.	0.03	0.26	0.36	0.45	0.53										
	25-26	1:20 p.m.	D. N. a.m.	1.46	7:18 p.m.	7:41 p.m.	0.35	0.12	0.22	0.44	0.60	0.69									
	29	12:05 a.m.	D. N. a.m.	0.61	12:09 a.m.	12:29 a.m.	0.01	0.24	0.38	0.44	0.51										
Sioux City, Iowa	9			1.52														0.24			
Spokane, Wash.	3-4			0.48														(*)			
Springfield, Ill.	29			1.49														0.50			
Springfield, Mo.	9-10	11:03 a.m.	D. N. a.m.	1.40	11:13 p.m.	11:32 p.m.	0.77	0.06	0.22	0.40	0.53										
Syracuse, N. Y.	26			0.47														(*)			
Tacoma, Wash.	15			0.85														0.16			
Tampa, Fla.	4	12:00 noon.	9:10 p.m.	1.47	12:59 p.m.	1:48 p.m.	0.39	0.12	0.19	0.35	0.42	0.42	0.46	0.63	0.71	0.80	0.88				
Tatoosh Island, Wash.	14			3.23														0.34			
Taylor, Tex.	9	1:35 p.m.	7:30 p.m.	1.96	2:09 p.m.	2:38 p.m.	0.01	0.24	0.39	0.57	0.98	1.25	1.51								
Terre Haute, Ind.	29			1.19														(*)			
Thomasville, Ga.	1-2	D. N. p.m.	8:15 a.m.	1.53	11:33 p.m.	12:35 a.m.	0.07	0.07	0.13	0.23	0.40	0.61	0.73	0.81	0.88	0.92	0.99	1.12	1.18		
	4	3:50 a.m.	7:37 a.m.	1.40	4:45 a.m.	5:01 a.m.	0.09	0.13	0.37	0.48	0.50										
Toledo, Ohio	29			0.79														0.24			
Tonopah, Nev.	27			0.13														(*)			
Topeka, Kans.	9			1.42														0.30			
Trenton, N. J.	4			0.50														0.44			
Valentine, Nebr.	9-10			1.11														(*)			
Vicksburg, Miss.	1	6:40 a.m.	8:50 a.m.	0.98	7:56 a.m.	8:20 a.m.	0.43	0.17	0.22	0.31	0.45	0.53									
	9-10	1:35 p.m.	4:10 p.m.	3.09	3:19 a.m.	3:45 a.m.	1.12	0.22	0.43	0.57	0.63	0.68	0.72								
	29	D. N. a.m.	9:15 a.m.	1.46	5:27 a.m.	5:55 a.m.	0.06	0.18	0.46	0.56	0.69	0.81	0.88								
Walla Walla, Wash.	3-4			1.23														(*)			
Washington, D. C.	13			0.60														0.30			
Wausau, Wis.	10			1.16														(*)			

* Self-register not in use.

‡ Precipitation not measured this month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during November, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Wichita, Kans	9			1.13														(*)			
Williston, N. Dak	2			0.29														(*)			
Wilmington, N. C	29			0.03														0.02			
Winnemucca, Nev	25			0.20														0.12			
Wytheville, Va	12			0.35														0.21			
Yankton, S. Dak	8-9			0.93														(*)			
Yellowstone Park, Wyo	30			0.31														(*)			

* Self-register not in use.

TABLE III.—*Data furnished by the Canadian Meteorological Service, November, 1919.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure. Station reduced to mean of 24 hours.	Pressure. Sea level reduced to mean of 24 hours.	Pressure. Departure from normal.	Temperature of the air. Mean max. + mean min. ÷ 2.	Temperature of the air. Departure from normal.	Temperature of the air. Mean maximum.	Temperature of the air. Mean minimum.	Temperature of the air. Highest.	Temperature of the air. Lowest.	Precipitation. Total.	Precipitation. Departure from normal.	Precipitation. Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F	125												
Sydney, C. B. I	48	30.01	30.06	+.11	39.6	+2.5	45.9	33.4	59	23	4.68	−0.76	3.5
Halifax, N. S	88	29.92	30.03	+.02	39.7	+2.4	46.4	32.9	58	20	7.59	+1.93	3.6
Yarmouth, N. S	65	29.93	30.00	+.01	41.1	+1.2	47.1	35.2	58	22	9.29	+4.73	2.4
Charlottetown, P. E. I	38	29.99	30.03	+.07	37.4	+1.9	42.0	32.8	53	15	3.32	+0.65	4.6
Chatham, N. B	28	30.04	30.07	+.10	33.6	+2.6	40.4	26.8	57	8	3.87	+1.12	5.2
Father Point, Que	20	30.02	30.04	+.08	29.3	+0.4	35.2	23.5	48	9	1.33	−1.78	8.1
Quebec, Que	296	29.72	30.06	+.04	30.6	+1.6	35.9	25.4	49	6	2.95	−0.81	9.3
Montreal, Que	187	29.84	30.06	+.03	33.0	+1.2	38.5	27.4	53	12	3.08	−0.66	10.7
Stonecliffe, Ont	489	29.44	30.07	+.06	23.3	−5.8	34.9	11.7	52	− 8	3.24	+0.66	6.6
Ottawa, Ont	236	29.80	30.14	+.12	32.5	+0.8	38.8	26.3	59	7	3.29	+0.75	8.3
Kingston, Ont	285	29.72	30.04	.00	36.0	+1.0	42.7	29.4	57	12	2.45	−0.79	0.8
Toronto, Ont	379	29.64	30.06	+.02	38.2	+2.6	45.1	31.2	64	16	1.63	−1.51	0.4
Cochrane, Ont	930	28.96			20.8		27.7	13.9	44	−20	2.34		16.0
White River, Ont	1,244	28.62	29.98	.00	20.7	+0.2	29.1	12.4	59	−24	3.87	+0.49	28.7
Port Stanley, Ont	592	29.43	30.09	+.04	37.3	+0.5	44.9	29.7	59	−18	2.40	−0.97	1.7
Southampton, Ont	656	29.30			35.9	+0.5	42.9	28.9	56	13	2.85	−0.85	7.7
Parry Sound, Ont	688	29.33	30.04	+.03	32.2	+0.1	39.9	24.5	55	0	5.00	+0.63	2.5
Port Arthur, Ont	644	29.30	30.03	+.03	23.8	−0.2	32.3	15.3	48	− 9	2.87	+1.54	10.5
Winnipeg, Man	760	29.24	30.12	+.08	13.2	−4.8	21.5	4.9	42	−19	2.28	+1.20	22.8
Minnedosa, Man	1,690	28.20	30.12	+.08	10.8	−6.5	19.9	1.7	41	−26	0.43	−0.57	4.3
Le Pas, Man	860	29.08			9.8		18.1	1.5	44	−24	0.57		5.7
Qu'Appelle, Sask	2,115	27.73	30.09	+.09	11.9	−6.9	19.9	4.0	46	−27	1.04	+0.15	10.4
Medicine Hat, Alb	2,144	27.69	30.03	+.03	20.8	−6.6	30.9	10.8	59	−18	1.15	+0.23	11.5
Moose Jaw, Sask	1,759	28.12			16.1		24.7	7.5	54	−22	0.88		8.8
Swift Current, Sask	2,392	27.38	30.11	+.09	16.5	−6.7	25.8	7.3	57	−27	0.15	−0.54	1.5
Calgary, Alb	3,428	26.39	30.11	+.13	20.0	−5.8	32.6	7.5	61	−13	0.78	−0.10	7.6
Banff, Alb	4,521	25.34	30.12	+.16	18.8	−7.0	28.1	9.5	49	−27	1.19	−1.08	8.5
Edmonton, Alb	2,150	27.67	30.06	+.09	13.3	−9.6	22.7	3.9	57	−39	1.89	+1.31	18.5
Prince Albert, Sask	1,450	28.48	30.13	+.10	11.7	−3.7	19.8	3.6	50	−24	1.05	+0.22	9.6
Battleford, Sask	1,592	28.27	30.09	+.07	13.6	−2.7	21.6	5.6	50	−28	0.58	0.00	5.8
Kamloops, B. C	1,262	28.85	30.17	+.21	30.5	−2.9	35.6	25.3	60	2	1.92	+0.46	14.0
Victoria, B. C	230	29.80	30.06	+.07	42.8	−0.4	46.7	38.9	55	30	5.53	−1.44	0.2
Barkerville, B. C	4,180	25.57	29.98	+.08	20.0	+3.6	26.8	13.3	45	−13	5.07	+1.78	31.6
Triangle Island, B. C	680												
Prince Rupert, B. C	170												
Hamilton, Ber	151	29.86	30.02	−.03	69.6	+0.9	74.5	64.8	81	56	4.28	−0.10	0.0

157307—20——5

SEISMOLOGY.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Jan. 3, 1920.]

TABLE I.—*Noninstrumental earthquake reports, November, 1919.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		ARKANSAS.								
	H. m.		° ′	° ′			Sec.			
Nov. 3	20 40	Pocahontas	36 15	90 55	5	1		Loud rumbling	Felt by many	Benedictine Sisters.
		CALIFORNIA.								
6	0 15	Redlands	34 04	117 12	4	1		None	Felt by several	P. W. Moore.
	0 15	Riverside	33 58	117 21	4	1		None	do	J. H. D. Cox.
25	11 03	Centerville	37 30	122 00	5	2		Loud rumbling	Felt by many	M. L. Mowry.
	11 03	Livermore	37 40	121 45	4	1		None	Felt by several	E. J. Still.
	11 03	Los Gatos	37 12	121 58	4	1		None	Felt by many	F. H. McCullagh.
	11 03	Petaluma	38 15	122 38	5	1		None	do	*Santa Rosa Press Dem'ct.*
	11 03	San Francisco	37 45	122 30	4	1	5	None	Many people awakened	U. S. Weather Bureau.
	11 03	San Jose	37 15	121 53	3	1	10	None	Felt by many	Maurice Connell.
	11 03	San Jose	37 15	121 53	3	1		None	do	U. S. Weather Bureau.
	11 03	Spreckles	36 35	121 38	3	2	2?	None	do	M. A. Klein.
	11 03	Stanford University	37 27	122 09	3	1	Few	None	do	S. D. Townley.
	11 15	Salinas	36 36	121 40	4	1	20	None	do	E. D. Eddy.

CORRIGENDUM.

REVIEW, September, 1919:
Page 688. The first quake on the 27th of September in the Toronto report should be deleted; it belongs to the Victoria report.

TABLE 2.—*Instrumental seismological reports, November, 1919.*

(Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.)

[For significance of symbols see REVIEW for January, 1919, p. 59.]

Alabama. *Mobile. Spring Hill College.* Seismic Observatory. Cyril Ruhlman, S. J.

Lat., 30° 41′ 44″ N.; long., 88° 08′ 46″ W. Elevation, 60 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

(No earthquake recorded during November, 1919.)

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 03″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		*V*	T_0
	E	10	17
	N	10	15

(No earthquake recorded during November, 1919.)

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		*V*	T_0
	E	10	17
	N	10	18

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov 14..	....	P_E....	6 48 36	3	......	......	......	N not in operation.
		M_E....	6 49 20	......	20	......	......	
		F_E....	6 53 —	......	......	......	......	

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

(Report for November, 1919, not received.)

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 03″ W. Elevation, 27.43 meters.

(*See* Record of the Seismographic Station. University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A.W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

(No earthquake recorded during November, 1919.)

District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulum, 80 kg. vertical.

Instrumental constants..		*V*	T_0	*ε*
	E	165	5.4	0
	N	143	5.2	0
	Z	*80*	*3.0*	*0*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 6	....	P_E....	7 19 29	....	......	......	......	Very heavy micros.
		P_N....	7 19 34	....	......	......	......	
		S_E....	7 25 36	....	......	......	......	
		S_N....	7 25 25	....	......	......	......	
		F.....	7 50 —	....	......	......	......	
18	....	e......	4 21 44	....	......	......	......	
		F.....	5 00 —	....	......	......	......	
18	....	L_E....	22 37 36	22	......	......	......	Very heavy micros.
		L_N....	22 33 26	24	......	......	......	
		F.....	23 ca.	....	......	......	......	
18	....	*eL_Z*...	*22 40 36*	....	......	......	......	Micros.
		L_Z....	*22 44 04*	*16*	......	......	......	
		F.....	*23 ca.*	....	......	......	......	
20	....	e_E.....	14 41 00	....	......	......	......	Very heavy micros.
		e_N.....	14 41 31	....	......	......	......	
		eL_E?..	15 14 36	....	......	......	......	
		L_E....	15 17 00	20	......	......	......	
		F.....	15 30 —	....	......	......	......	
20	....	*e_Z*.....	*14 41 48*	....	......	......	......	Very heavy micros.
		L_Z....	*15 14 59*	*16*	......	......	......	
		F.....	*15 30* ..	....	......	......	......	
28	....	e_E?....	14 20 00	....	......	......	......	Very heavy micros; difficult.
		e_N?....	14 23 00	....	......	......	......	
		L.....	14 27 50	15	......	......	......	
		F.....	14 38 ..	....	......	......	......	

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.

	V	T_0
Instrumental constants..	110	6.4

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 6	....	e......	7 24 00	....	......	......	......	Heavy micros; phases indeterminable.
		F.....	7 40 ca.	....	......	......	......	
18	....	e......	4 21 00	....	......	......	......	Phases indeterminable.
		F.....	4 35 00	....	......	......	......	
18	....	S?.....	22 16 16	....	......	......	......	
		L.....	22 28 45	28	......	......	......	
		L.....	22 33 30	20	......	......	......	
		L.....	22 40 ..	16	......	......	......	
		F.....	23 ca. ..	....	......	......	......	
20	....	eL....	14 40 ..	....	......	......	......	
		L.....	15 15 ..	20	......	......	......	
		L.....	15 18 ..	16	......	......	......	
		F.....	15 45 ..	....	......	......	......	
28	....	e......	14 22 00	....	......	......	......	
		L.....	14 27 50	16	......	......	......	
		F.....	14 35 ca.	....	......	......	......	

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant.. T_0 18.4. Sensitivity, 0.40″.

(Report for November, 1919, not received.)

TABLE 2.—*Instrumental seismological reports, November, 1919*—Continued.

Illinois. *Chicago.* University of Chicago. U. S. Weather Bureau.

Lat., 41° 47′ N.; long., 87° 37′ W. Elevation, 180.1 meters.

Instruments: Two Milne-Shaw horizontal pendulums, 0.45 kg.

Instrumental constants		V	T_0	ϵ	Sensitivity.
	E.	150	12	20:1	1″ arc tilt=26.6 mm.
	N.	150	8	20:1	1″ arc tilt=13.2 mm.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 6	....	P?.....	7 21 25	....	....	....	......	
		S.....	7 26 04	....	....	....	......	
		L.....	7 28 30	....	....	....	......	
		L.....	7 34 ..	20	....	....	......	
		F.....	8 10 ca.	....	....	....	......	
14	....	P.....	6 49 41	....	....	....	......	
		S?.....	6 56 38	....	....	....	......	
		F.....	7 20 ca.	....	....	....	......	Lost in micros.
18	....	P.....	4 21 07	....	....	....	......	
		L.....	4 40 ..	18	....	....	......	
		L.....	4 58 ..	15	....	....	......	
		L.....	5 14 ..	15	....	....	......	
		F.....	5 40 ca.	....	....	....	......	Lost in micros.
18	....	S?.....	22 16 06	....	....	....	......	
		L.....	22 34 ..	22	....	....	......	
		L.....	22 40 ..	18	....	....	......	
		L.....	22 45 ..	15	....	....	......	
		F.....	23 50 ca.	....	....	....	......	Lost in micros.
20	....	P.....	14 30 30	....	....	....	......	
		S.....	14 40 05	....	....	....	......	
		L.....	14 46 50	....	....	....	......	
		L.....	15 07 ..	25	....	....	......	
		L.....	15 11 ..	18	....	....	......	
		L.....	15 20 ..	16	....	....	......	
		F.....	17 ca. ..	....	....	....	......	Lost in heavy micros.
23	....	L.....	6 56 ..	22	....	....	......	Heavy micros; P. and S. not discernible.
		L.....	7	20	....	....	......	
		L.....	8 05 ..	15	....	....	......	
		F.....	8 30 ..	....	....	....	......	
28	....	P.....	14 21 00	....	....	....	......	Micros.
		S.....	14 27 08	....	....	....	......	
		L.....	14 29 45	17	....	....	......	
		F.....	16 ca. ..	....	....	....	......	

Kansas. *Lawrence.* *University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Weichert.

Instrumental constants		V	T_0	ϵ
	E	177	3.4	4:1
	N	205	3.4	4:1

(Report for November, 1919, not received.)

Maryland. *Cheltenham.* *Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants		V	T_0
	E	10	14
	N	10	14

(No earthquake recorded during November, 1919.)

Massachusetts. *Cambridge.* *Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration)

Instrumental constants		V	T_0	ϵ
	E	80	23	0
	N	50	25	4:1

(Report for November, 1919, not received.)

Missouri. *Saint Louis.* *St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants	V	T_0	ϵ
	80	7	5:1

(Report for November, 1919, not received.)

New York. *Buffalo.* *Canisius College.* John A. Curtin, S. J.

Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.

Instrument: Wiechert 80 kg. horizontal.

Instrumental constants	V	T_0	ϵ
	80	7	5:1

(Report for November, 1919, not received.)

New York. *Ithaca.* *Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori 25 kg. horizontal pendulums (mechanical registration.)

Instrumental constants		V	T_0	ϵ
	E	13	22	4:1
	N	14	25	4:1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Nov. 18	....	e_E.....	22 13 50	10	....	....	......	
		L_E.....	22 23 50	25	....	....	......	
		F_E.....	23 10 ..	....	....	....	......	
20	....	L_E.....	15 15 50	20	....	....	......	Earlier phases lots in micros.
		F_E.....	15 38 ..	....	....	....	......	

New York. *New York.* *Fordham University.* D. H. Sullivan, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert 80 kg.

Instrumental constants		V	T_0	ϵ
	E	72	5.0	0
	N	72	5.0	0

(Report for November, 1919, not received.)

Panama, Canal Zone. *Balboa Heights.* Governor, Panama Canal.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg. and 25 kg.

Instrumental constants	V	T_0
	35	20
	10	20

(Report for November, 1919, not received.)

Porto Rico. *Viegues.* *Magnetic Observatory.* U. S Coast and Geodetic Survey. W. M. Hill.

Lat., 18° 09′ N.; long. 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants		V	T_0
	E	10	17
	N	10	19

(Report for November, 1919, not received.)

TABLE 2.—*Instrumental seismological reports, November, 1919*—Continued.

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

		V	T_0
Instrumental constants..	E	10	15
	N	10	16

(No earthquake recorded during November, 1919.)

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80 kg. vertical seismograph.

Instrumental constants..120 (V) 26 (T_0)

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 6		L_E	7 27					N.-S. masked by micros.
		L_E	7 29	15				
		L_E	7 33	15				
		F	7 40	15				
18		i	4 21 27					L waves sinusoidal, but so small in amplitude as to be barely visiole.
		L_E	4 38 to					
			5 15					
		F	5 25					
18		iS?	22 15 23					Micros interfere with any preceding phases.
		eL	22 26 24	40				
		L	22 30	25				Sinusoidal L waves which are remarkable for the similarity on both components.
		L	22 39	16				
		L_E	22 58	9				
		F	23 10					
20		$e?_E$	14 41 09					
		eL?	15 05					
		L	15 14					
		L_E	15 18 to					
			15 30	18				
		F	15 36					
23		L_E	6 58 to					
			7 11	24				
		L_E	7 13 to					
			7 18					
		L_E	7 23					
		F	7 28					
28		$iS_N?$	14 19 18					This quake, though smaller, bears a striking resemblance to the second quake on Nov. 18, above.
		$iS?_E$	14 19 24					
		eL	14 23 40	15				
		L_E	14 28 to					
			14 32	13				
		F	14 35					

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant..18 (T_0). Pillar deviation, 1 mm. swing of boom=0.45″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 1		eL	5 58 06					Gradual thickening.
		M	5 59 42		*200			
		F	6 07 18					
6		L	7 27 48					
		eL	7 39 06		*100			
		F	7 45 06					
18		L	4 31 18					
		L	4 45 00		*50			
		L	4 46 18					

* Trace amplitude.

Canada. *Toronto. Dominion Meteorological Service*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 18		e	22 06 18					P. waves not defined.
		e	22 12 30					
		S	22 14 48					
		L	22 24 30					
		L	22 35 00					
		L	22 39 36					
		eL	22 40 48					
		M	22 41 36		*1,300			
		F	23 42 54					
20		e	14?37 12					Small micros interfered with initial phases.
		L	14 41 18		*100			
		L	14 58 12					
		L	15 15 00					
		eL	15 19 00					Marked thickening 15 19 to 15 26 12.
		M	15 24 12		*800			
		F	16?03 00					
20		L	16 28 54		*50			
		F	17 09 48					
23		e	7 03 30					
		eL	7 11 42					
		M	7 18 18		*200			Gradual thickening.
		F	7 31 54					
28		e	14 12 30					Asia Minor. Micros interfered with definition of waves.
		L	14 22 30					
		L	14 25 42					
		M	14 29 42					
		F			*100			Micros.

*Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instrument: Wiechert, vertical; Milne horizontal pendulum, North; in the meridian.

Instrumental constant..18 (T_0). Pillar deviation, 1 mm. swing of boom=0.54″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 6		P?	7 47 51					
		M	7 51 47		*300			
		F	8 03 36					
14		P	6?57 06					
		L	6 58 35					
		M	7 02 32		*300		656?	
		F	7 16 18					
18		P	4 23 04					
		S	4 31 26					
		L	4 45 41					
		M	4 54 47		*500		6,860	
		F	5 17 10					
18		P?	22 29 32					
		S?	22 34 27					
		L	22 40 51					
		M	22 48 13		*500		3,170?	
		F	23 25 06					
20		P	14 24 15					
		S	14 27 52					
		L?	14 34 05					
		M	14 37 32		*400		2,160	
		eL	14 56 52					
		F	15 25 14					
20		M	16 43 56		*200			
		F	17 00 40					
23		P	6 23 31					
		S	6?30 24					
		L	6 38 16					
		M	6 46 38		*400		5,200?	
		F	7?09 45					
28		P?	14 04 28					
		M	14 35 27		*200			Asia Minor?

* Trace amplitude.

SEISMOLOGICAL DISPATCHES.[1]

Guatemala City, Guatemala, October 14, 1919.

A severe earthquake was felt this day at Amatitlan, a town situated about 25 kilometers from this place. At Puerto Barrios its intensity was such as to cause general alarm. (Georgetown Cooperative Station.)

Florence, Italy, October 26, 1919.

Homes and schools were abandoned in a panic here when an earthquake rocked the city yesterday afternoon. The quake was a strong undulating movement of the ground, especially heavy in Avezzo and Valdarno, where heavy damage was reported. The tremor was also felt at San Repolero and throughout the valley of Arno and Chiana. (Associated Press.)

Quebec, Canada, October 27, 1919.

An earthquake shock was recorded on the north shore of the Gulf of St. Lawrence early Sunday morning. It started at 5.28 and the tremor was felt for two minutes. No damage reported. (Associated Press.)

Fort de France, Martinique, November 7, 1919.

Quite a strong earthquake shock was felt here at 3.15 this morning. No serious damage resulted. (Associated Press.)

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C.

Salta, Argentina, November 10, 1919.

A strong earthquake shock, lasting several seconds, was felt here shortly after last midnight. The tremors were repeated at 5 o'clock this morning with less intensity. No damage has been reported.

San Francisco, November 25, 1919.

Portions of San Francisco were shaken for half a minute early this morning by an earthquake. No damage was reported, though sleepers were jarred from their beds. The quake occurred at 3.04 o'clock. (United Press.)

Detroit, Mich., November 27, 1919.

That a meteor of tremendous size plunged into Lake Michigan last night, causing earth tremors felt in a dozen southern Michigan cities and sending a pillar of flame hundreds of feet into the air which was visible for a radius of more than 50 miles, was the theory generally accepted early to-day in explanation of the earth shock which at first was believed to have been caused by a terrific explosion at some industrial plant. (Associated Press.)

Paris, November 29, 1919.

A slight earthquake shock, lasting seven seconds, was felt at 20 minutes to 10 o'clock last night at Cannes, in the Riviera, it was announced in messages received here this morning. A heavier shock was experienced a half hour after midnight at Foix, 45 miles south of Toulouse, at the foot of the Pyrenees. Only slight damage was done at either place. (Associated Press.)

TABLE 3.—LATE REPORTS. (INSTRUMENTAL.)

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.: long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg. horizontal pendulums (mechanical registration).

Instrumental constants: E: V 13, T_0 22, ϵ 4:1; N: V 14, T_0 25, ϵ 4:1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	Km.	
Sept. 6		P_N	9 35 44	4				Clock out of order. Clock error uncertain throughout month.
		S_E	9 40 03	7				
		S_N	9 40 07	6				
		L_N	9 41 13	11				
		L_E	9 41 17	11				
		F_E	10 27 ..					
13		e_N	12 30 15	4				
		i_E	12 38 17	5				
		i_N	12 38 18	5				
		L_N	12 52 ..	20				
		F_N	13 09 ..					
15		i	17 49 15	5				Phases lost in micros.
		F	18 05 ..					
27		e_N	11 33 10	3				e_N may be micros. Phases overlapping. Origin not far away.
		e_E	11 33 39	3				
		F_N	11 39 ..					
30		e_N	7 55 15	4				
		e_E	7 55 52	11				
		F	8 12 ..					
Oct. 3		L_E	10 37 ..	18				
		F_E	10 58 ..					
10		L	1 27 06	18				
		F	2 01 ..					
12		e_N	22 11 12	4				
		eL_N	23 13 15	24				
		F	23 27 ..					
27		P_N	3 50 30	4				
		e_E	3 52 59	5				
		eS	3 58 24	5				
		L_E	4 08 18	16				
		F_E	4 17 ..					

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. W. M. Hill.

Lat., 19° 09′ N.; 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants: E: V 10, T_0 17; N: V 10, T_0 19

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	Km.	
Oct. 14		L_E	17 03 17					Nothing on N. Times obtained by interpolation over an interval of 12 hours.
		M_E	17 05 35	17	10			
		F_E	17 15 ..					

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.: long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant: T_0 18.4. Sensitiveness 0.40″ arc tilt-1 mm.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			H. m. s.	Sec.	μ	μ	Km.	
Oct. 3		iP	9 51 18	17	*3,300			The actual maximum, 3,300, occurs at 9.56, and probably obscures the beginning of L.
		iS	9 54 30					
		eL	10 00 12					
		M	10 06 30	16	*1,100			
		C	10 22 ..	15				
		F	11 36 ..	18				
6		L	2 04 36					
		M	2 08 12		*100			
		F	2 19 ..					
8		eP	4 50 18	18				
		S	4 58 30	17				
		eL	5 09 24					
		M	5 22 00	17	*500			
		C	5 29 ..	17				
		F	6 30 ..	18				
10		L	1 18 18					
		M	1 27 00	16	*2,000			
		C	1 30 00	17				
		F	2 40 ..	16				
21		P	21 39 18	21				
		L	21 49 24	22				
		M	21 59 30	16	*400			
		C	22 05 30	16				
		F	22 50 ..	19				
23		P	0 43 24					
		M	0 44 24		*400			
		C	0 46 ..					
		F	0 49 ..					
23		eP	16 23 30					Hourly time breaks missing. Times obtained by interpolation over a period of 17 hours.
		eL	16 41 ..					
		M	16 49 00	15	*100			
		C	16 54 30					
		F	20 34 ..					
26		L	19 29 ..					
		M	19 36 30	18	*100			
		C	19 42 ..					
		F	21 18 ..					
27		P	4 04 54					
		M	4 07 12	20	*100			
		C	4 10 30					
		F	4 38 ..					
31		eP	19 35 18					
		L	19 43 00					
		M	19 46 18	15	*100			
		C	20 02 ..	17				
		F	20 10 ..	19				

* Trace amplitude.

THE VIRGINIA EARTHQUAKE OF SEPTEMBER 5, 1919.

By EDGAR W. WOOLARD, Assist. Observer.

[Dated: Weather Bureau, Washington, D. C., Dec., 1919.]

Distinct earthquake shocks were felt over the Blue Ridge region of Warren and Rappahannock counties, Virginia, about 10 p. m. local standard "summer" time, September 5, 1919, or 2 h. Greenwich civil time, September 6. The shocks were apparently of greatest intensity in Harmony Hollow, a valley to the east of Dickeys Hill, between the latter and the crest of the main Blue Ridge and a few miles south of Front Royal, or near Arco. This same area was the one of highest intensity in the earthquake of April 9, 1918. A report, by Dr. T. L Watson, of the Virginia Geological Survey, on the geology of this region as related to the two disturbances will appear in the *Bulletin* of the Seismological Society of America.

The quake appears to have been entirely local. It was distinctly registered at Washington, D. C., on the seismographs of the U. S. Weather Bureau and Georgetown University, as a very small brief disturbance; it was not noticeable to the senses, however, more than 40 miles from Front Royal. Inquiries directed to Winchester, Strasburg, Woodstock, Mount Weather, Rectortown, and Waterlick failed to locate anyone who had felt the shocks.

There was a gradual onset of trembling shocks, intensity 4 (adapted Rossi-Forel), one mile north of Front Royal, there being two shocks, each lasting about three minutes, accompanied by a rumbling sound; many people felt these. The disturbance was felt, intensity 4, at Riverton, and by many people at Limeton; also, one-half mile southeast of Reager. Trembling shocks, intensity 3, lasting three minutes, were felt by many people in and near Cedarville, but no damage was done. At Arco, rocking shocks, intensity 8, with loud rumbling sound were reported by J. A. Silman, who states that "this earthquake caused a good bit of excitement; some never-failing springs are dry since, and the rocks fell from chimneys, this occurring about one-half mile north of Arco; springs around in the neighborhood of 2 miles were muddy next day; there have been slight quakes since, but I haven't the exact date." Chas. M'Clure was writing in his office in Front Royal "when there was a sudden heavy jar, and a sound as if something had fallen in some part of the building." Near Arco he found that "considerable excitement ensued from repeated severe shocks accompanied on the first shock by an explosive sound as if of a heavy blast, and on the second shock about an hour later, a still heavier explosion of the same character. Several subsequent shocks are reported." Plaster fell from walls, and glassware from shelves. Children were panic-stricken, and one was thrown into convulsions. A widespread phenomenon was that of many clear streams suddenly becoming, and remaining, turbid, although there had been no rain.

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Chart I. Hydrographs of Several Principal Rivers, November, 1919.

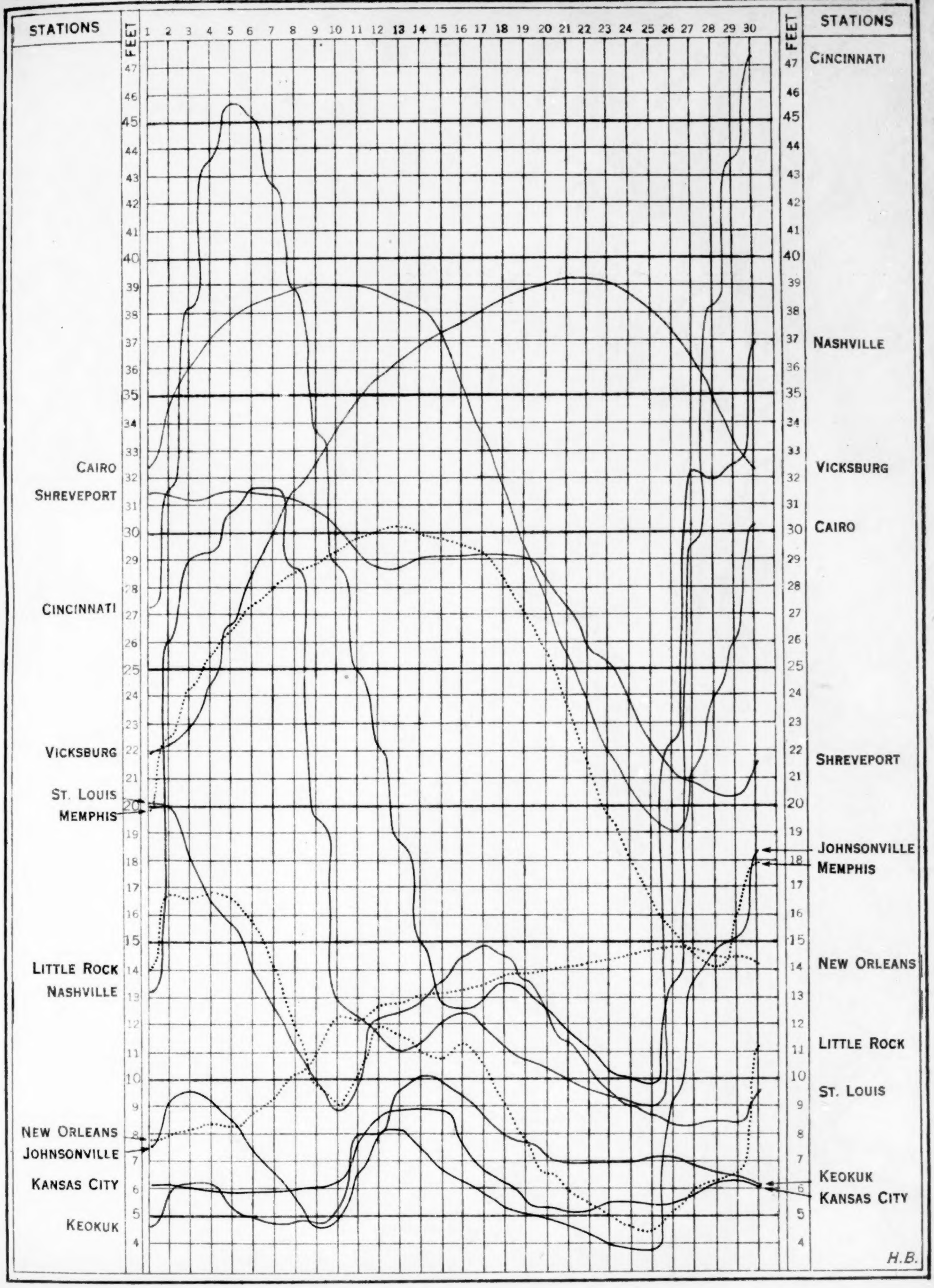


Chart II. Tracks of Centers of High Areas, November, 1919.
(Plotted by R. H. Weightman, Meteorologist.)

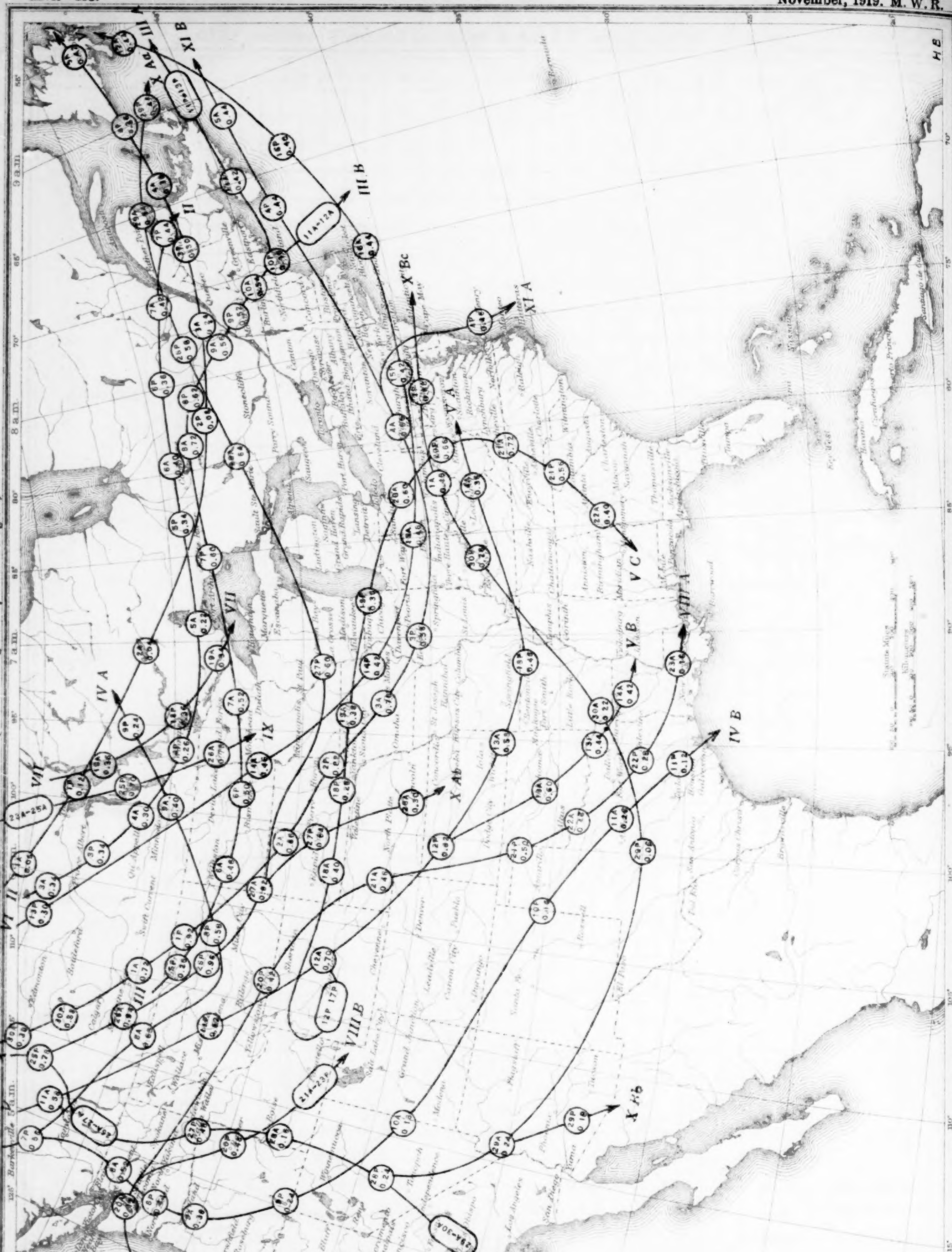


Chart III. Tracks of Centers of Low Areas, November, 1919.

Chart III. Tracks of Centers of Low Areas, November, 1919.
(Plotted by R. H. Weightman, Meteorologist.)

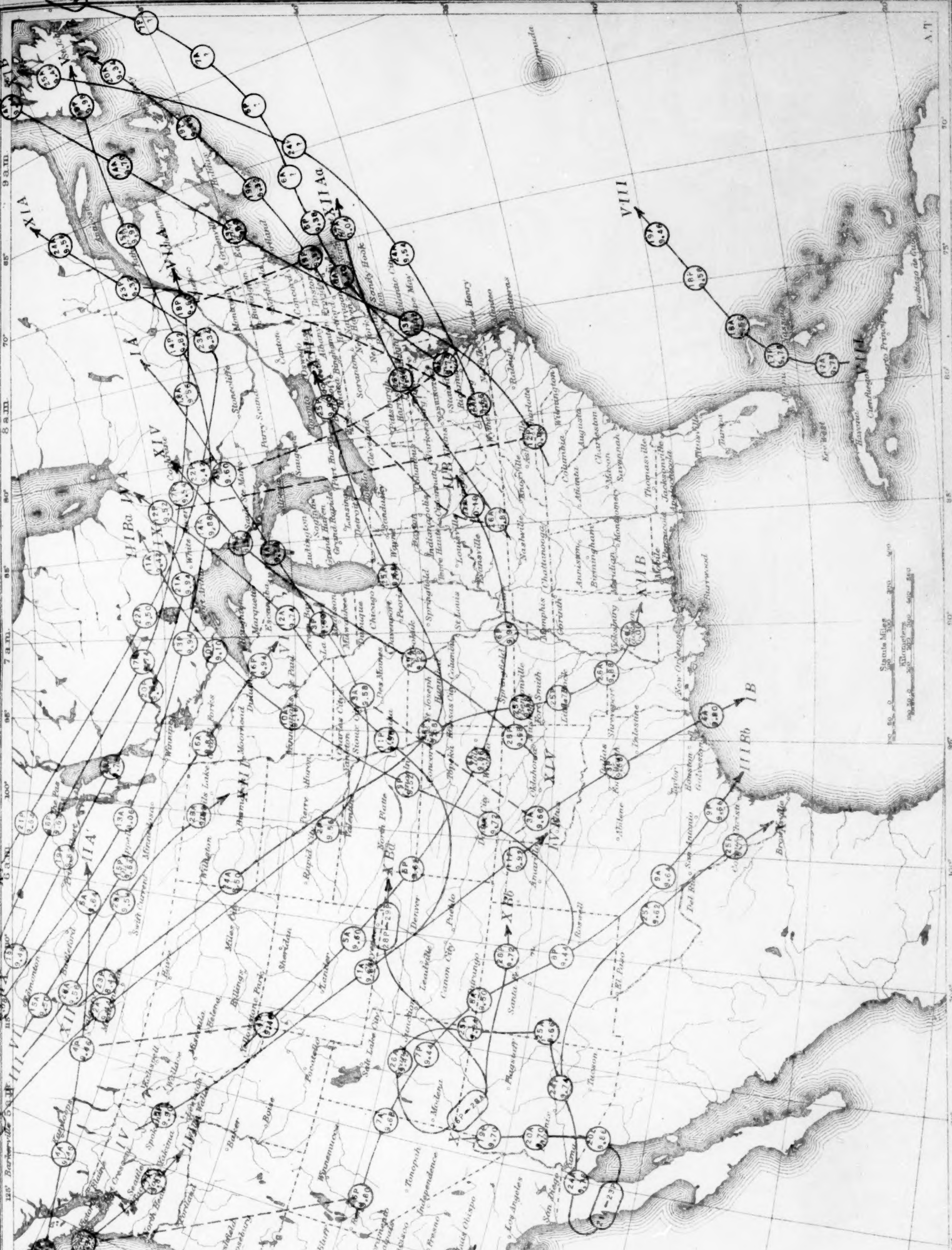


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, November, 1919.

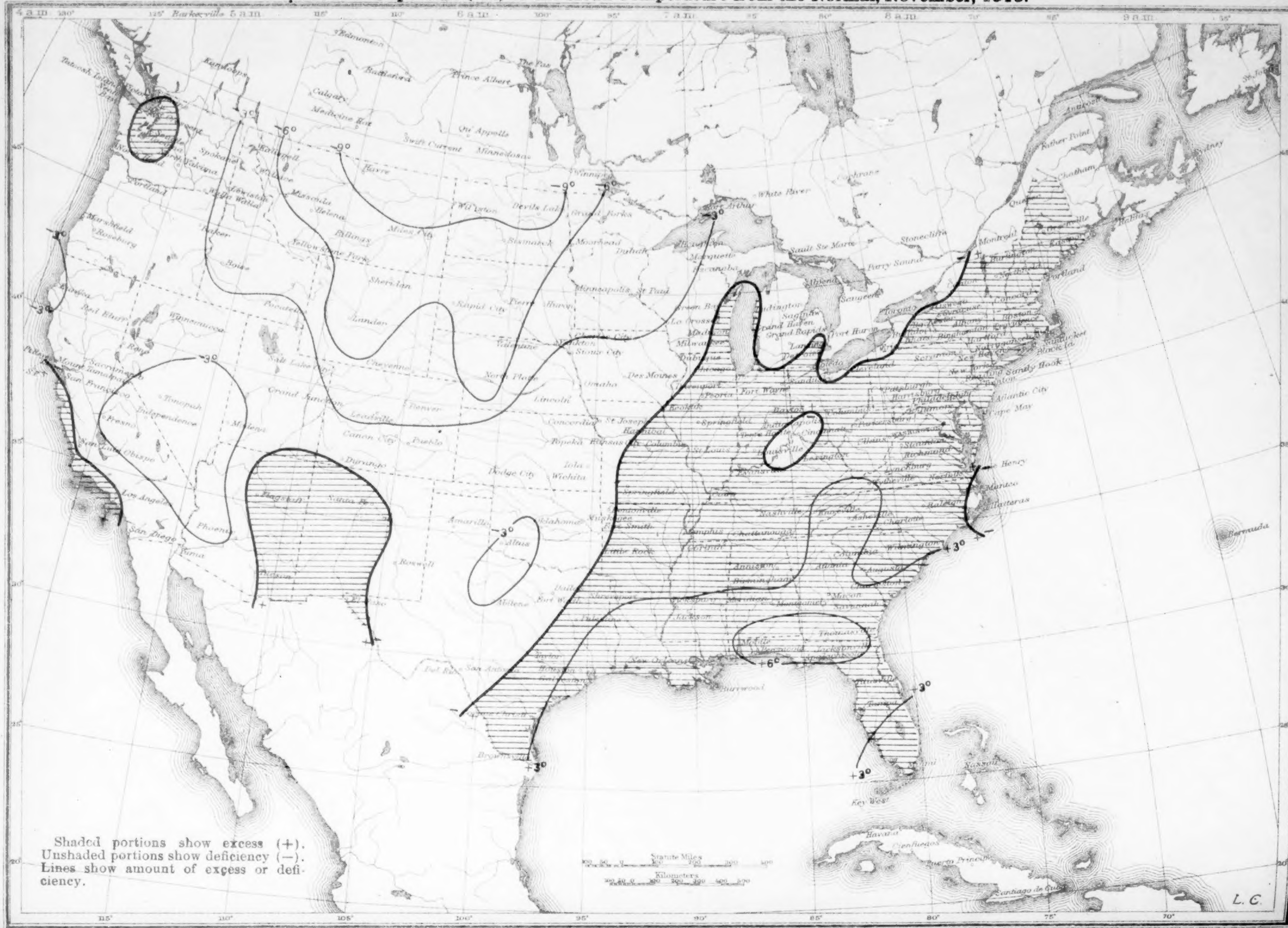


Chart V. Total Precipitation, Inches, November, 1919.

Chart V. Total Precipitation, Inches, November, 1919.

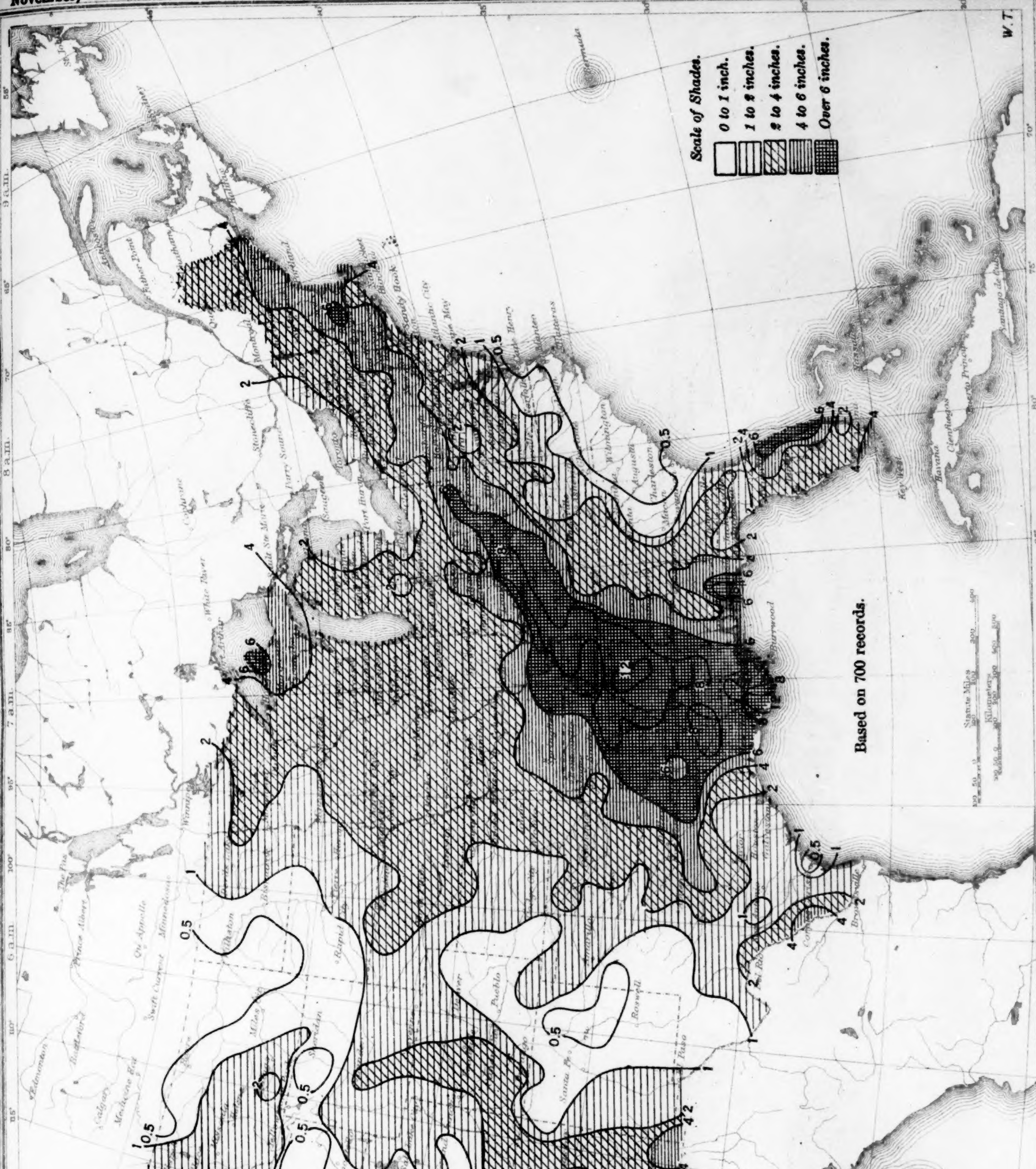


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, November, 1919.

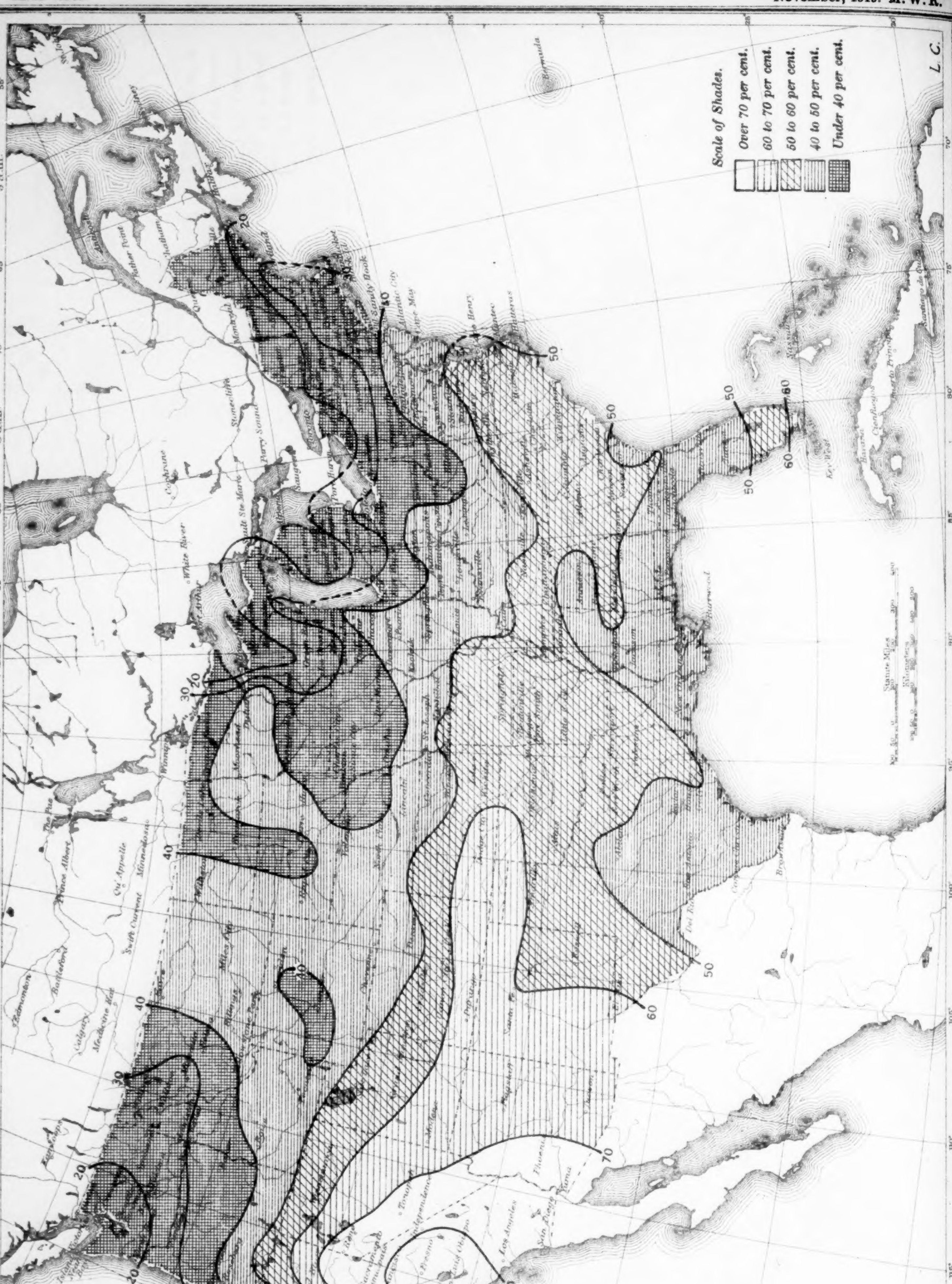


Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, November, 1919.

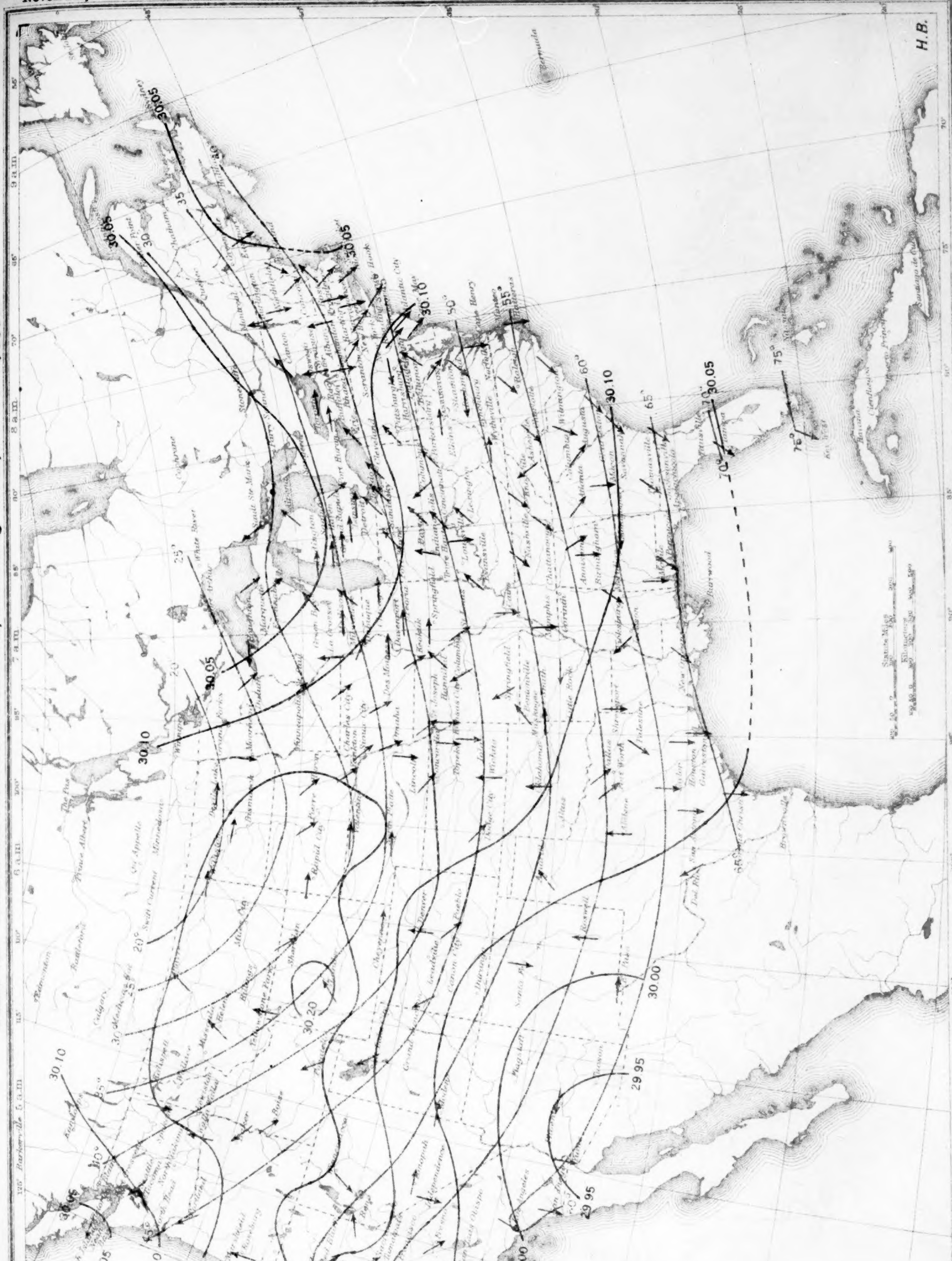


Chart VIII. Total Snowfall, Inches, November, 1919.

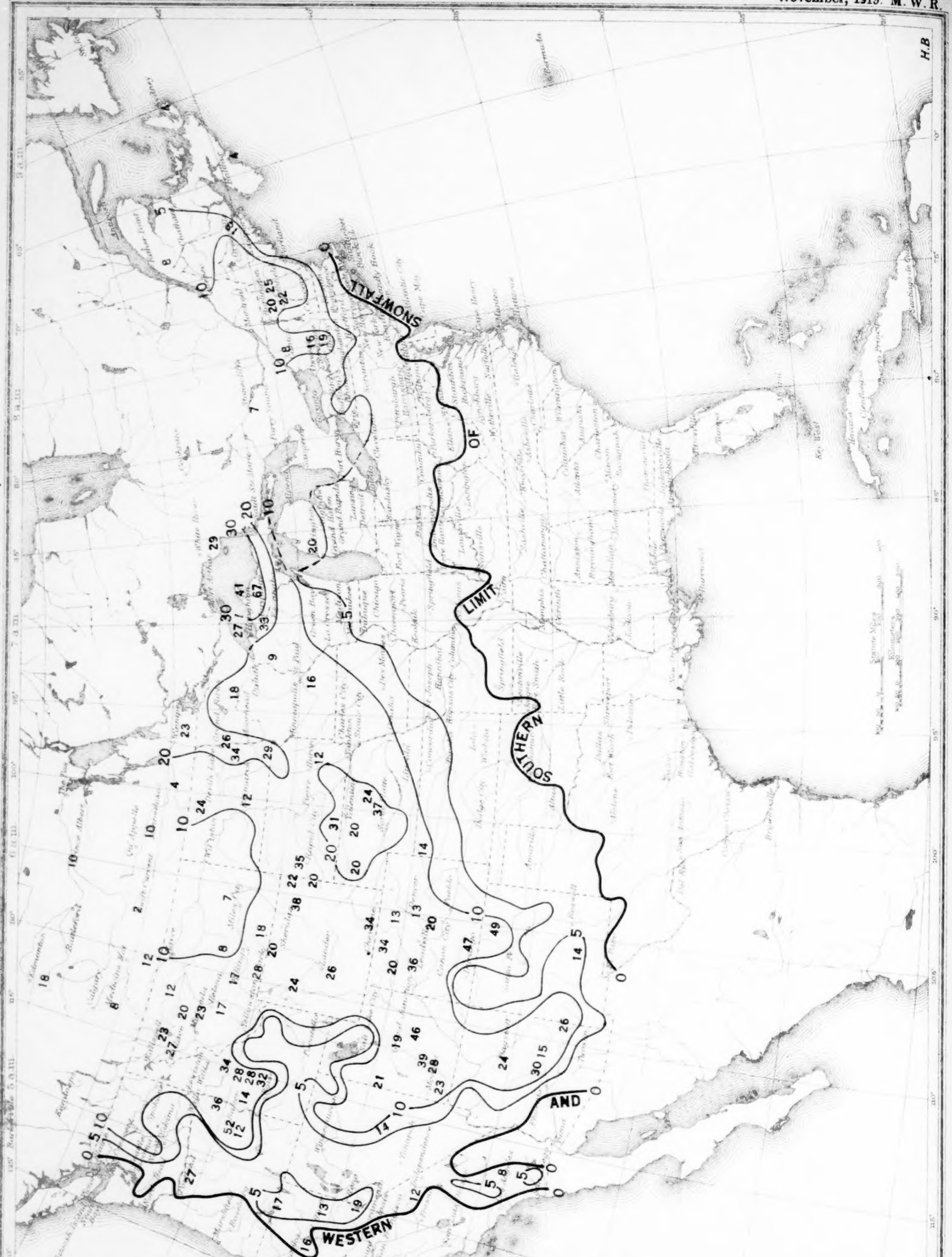


Chart IX. Weather Map of North Atlantic Ocean, November 1, 1919.
(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, November 1, 1919.

(Plotted by F. A. Young.)

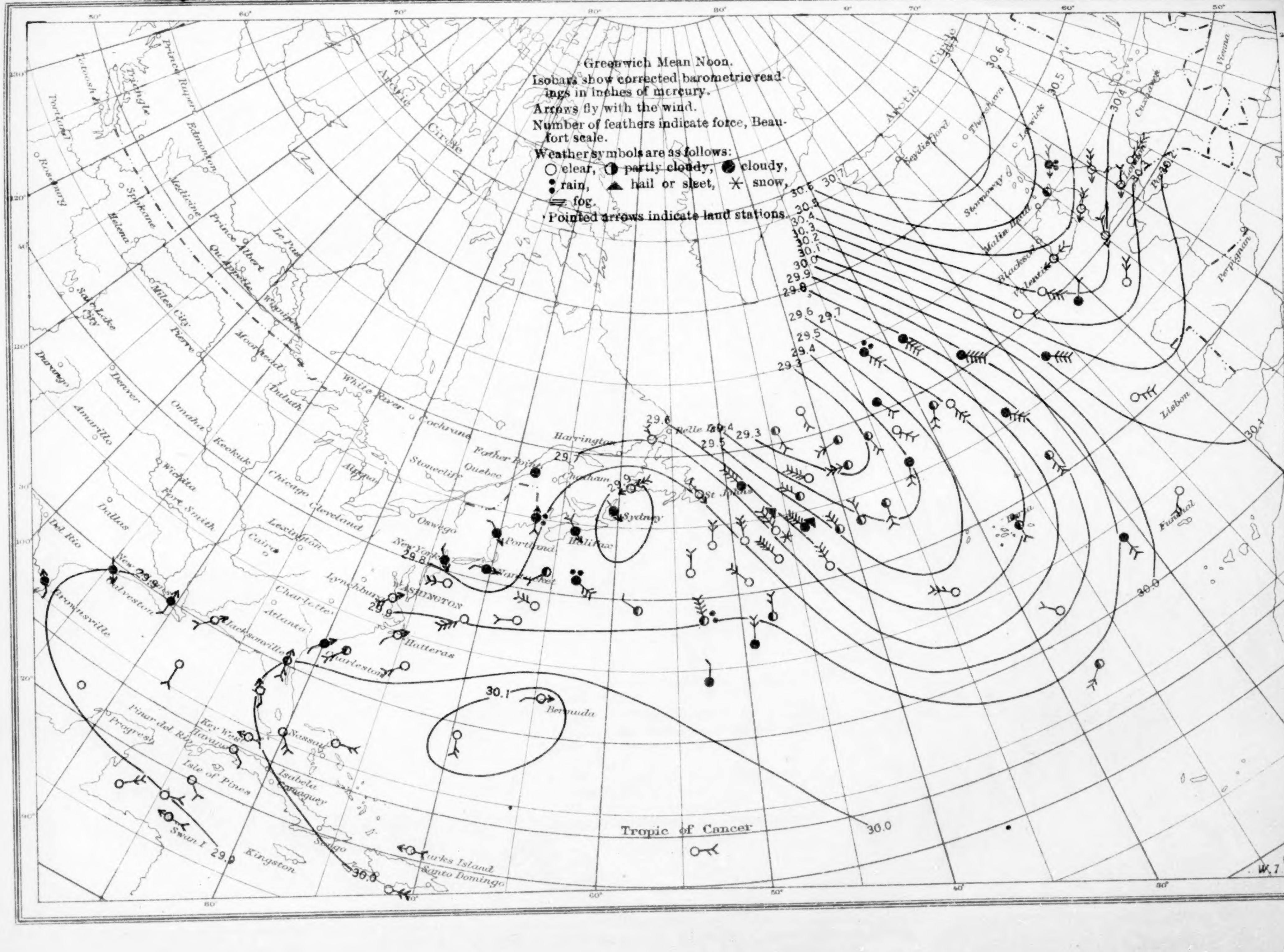


Chart X. Weather Map of North Atlantic Ocean, November 6, 1919.
(Plotted by F. A. Young.)

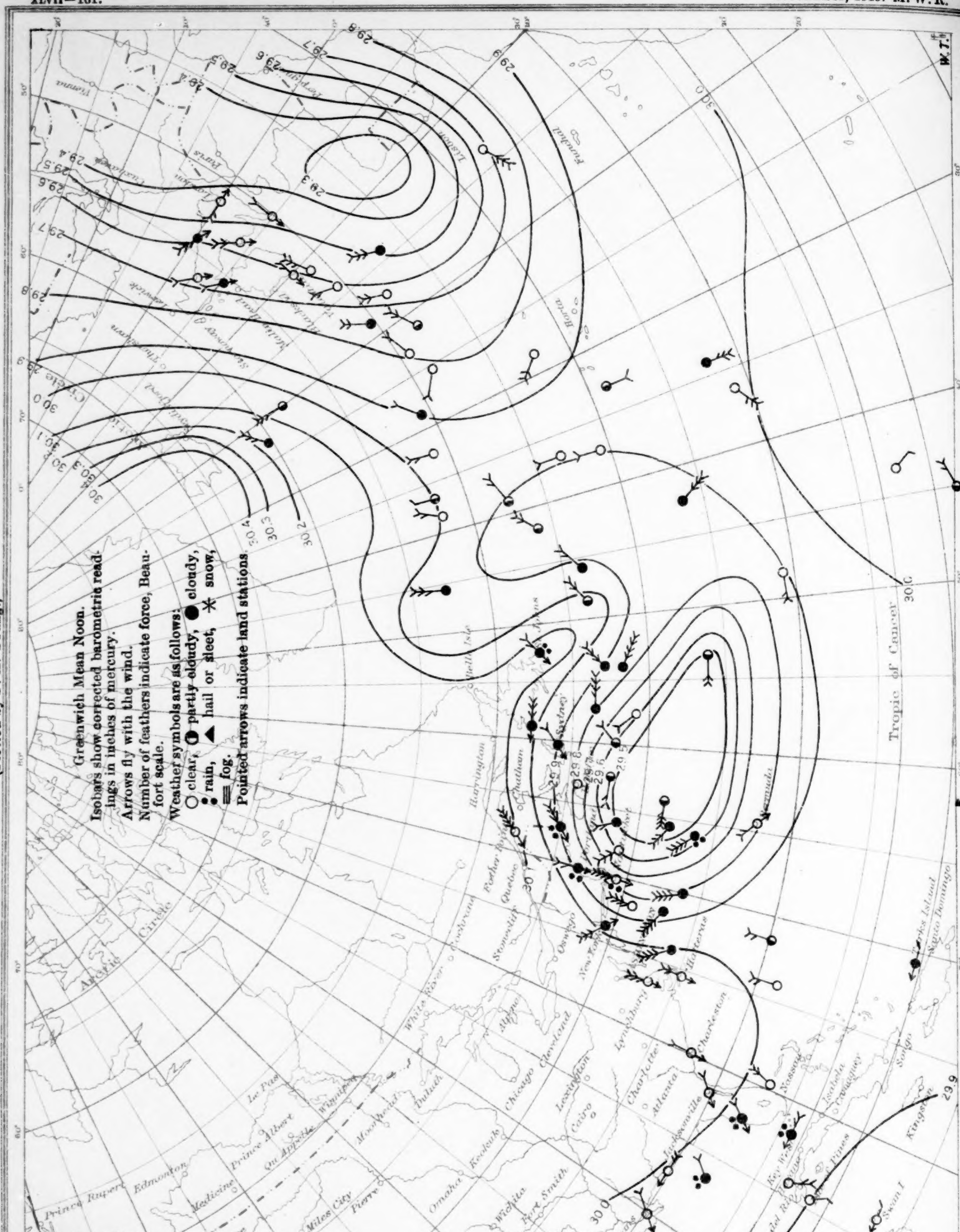


Chart XI. Weather Map of North Atlantic Ocean, November 7, 1919.
(Plotted by F. A. Young.)

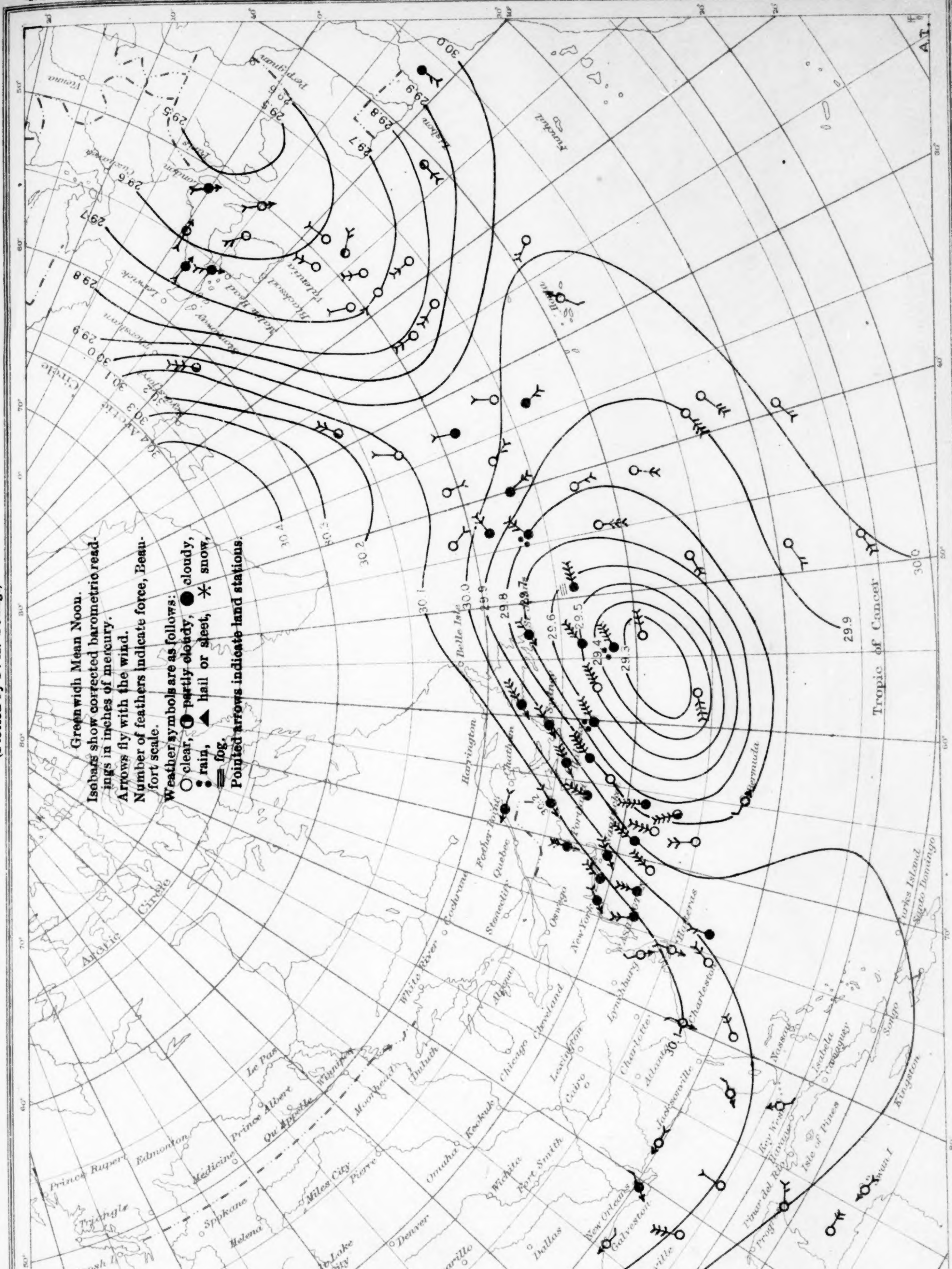


Chart XII. Weather Map of North Atlantic Ocean, November 8, 1919.

(Plotted by F. A. Young.)

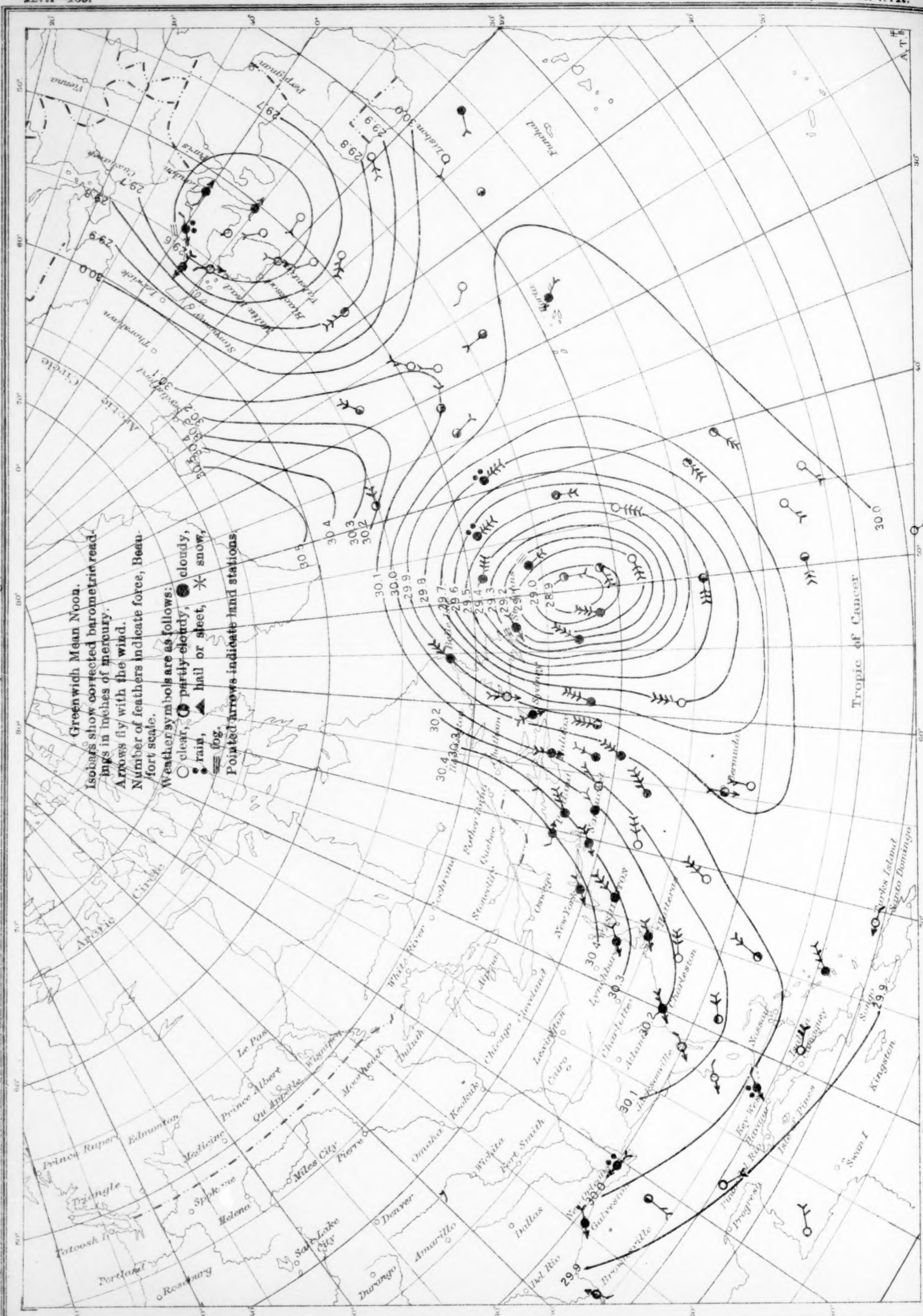
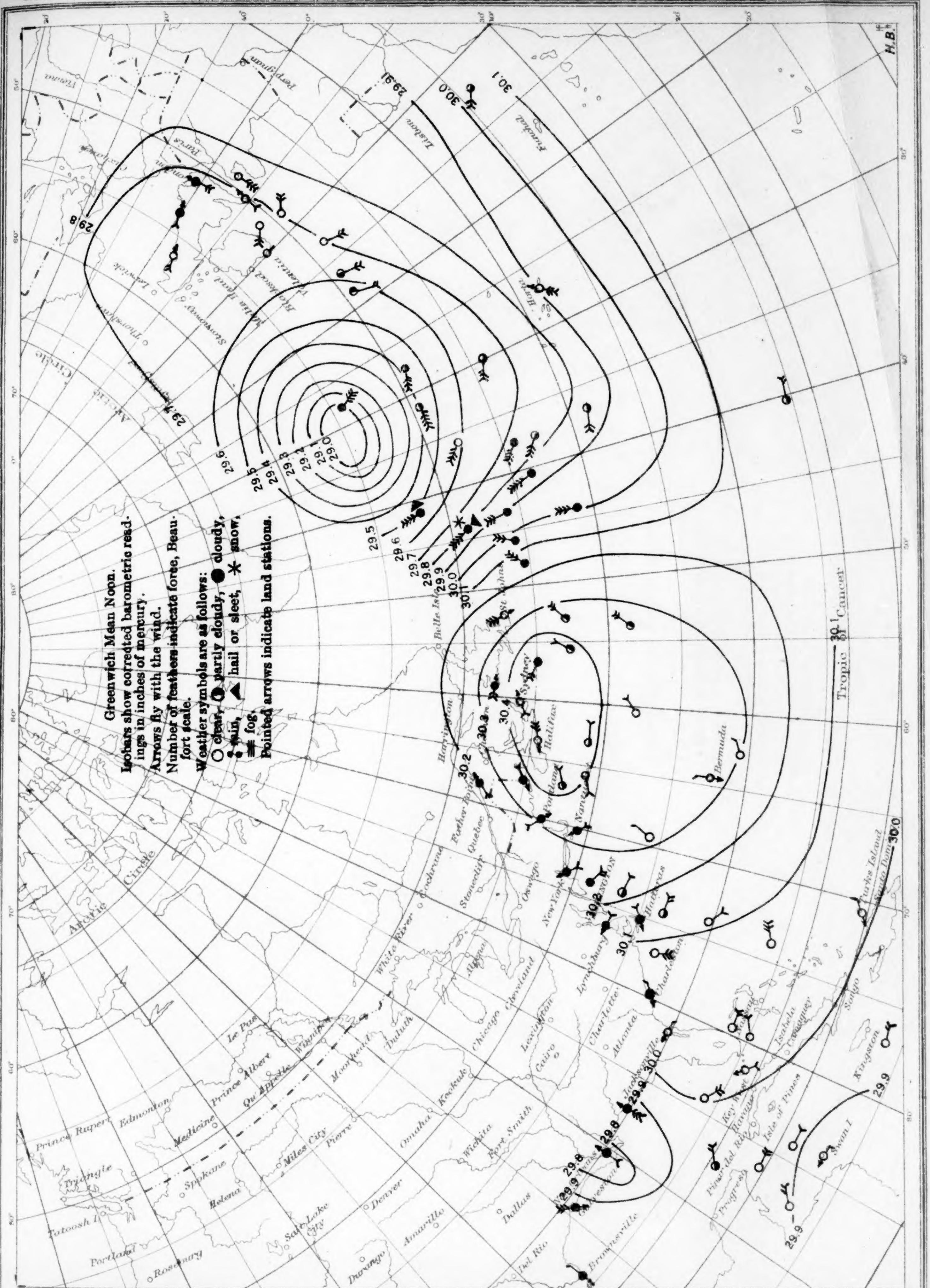


Chart XIII. Weather Map of North Atlantic Ocean, November 29, 1919.
(Plotted by F. A. Young.)



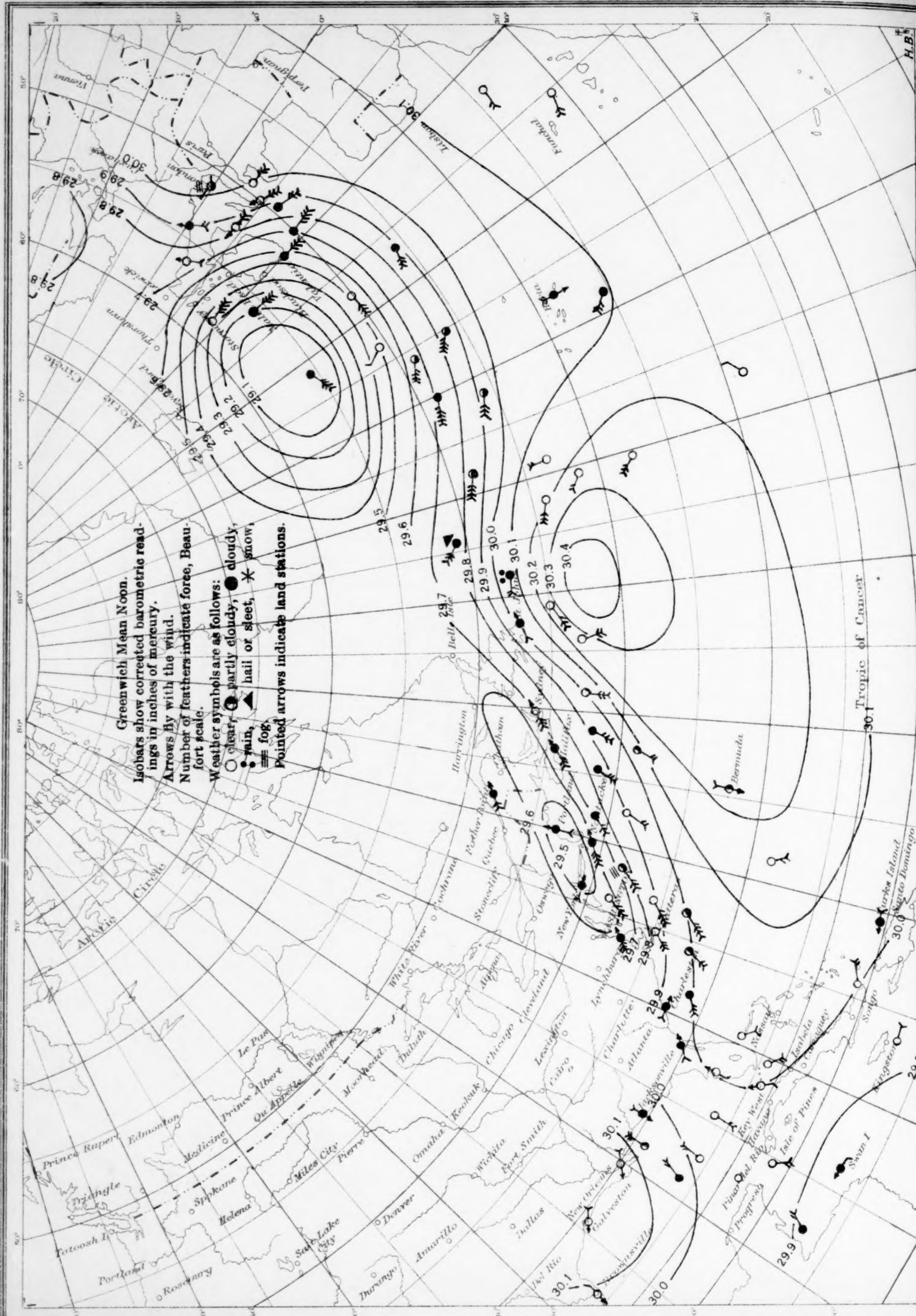


Chart XIV. Weather Map of North Atlantic Ocean, November 30, 1919.
(Plotted by F. A. Young.)